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Effect of Individual Height and Testing Methods on Outcome of the Forward Functional Reach Test

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The Effect of Individual Height and Testing Methods on Outcome of the Forward Functional Reach Test

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ABSTRACT

Background: With falls a leading cause of injuries among those over age 65, early recognition of risk is imperative to reduce rising rates. The Forward Functional Reach test (FFRT) (Duncan et al., 1990) is frequently used to identify fall risk, however the variability in cut values found in the research may be related to height and reach strategies.

Purpose: The purpose of this study was to determine if FFRT is affected by an individual's height, and if bilateral reach to height ratio could more accurately identify fall risk.

Methods: Sixty-six participants (60 and older) were recruited from a senior center in Alabama. Inclusion criteria required ability to stand for two minutes, walk independently with or without an assistive device for 20', no restrictive neurological/orthopedic injury or vital signs. Participants were classified into height groups; short < 65", medium 65" to 69", or tall > 69" and as fall risk (1) or non-fall risk (0) based on health/fall history, Activities-Specific Balance Confidence Scale (ABC), Timed Up and Go (TUG), and hand grip strength; summative as fall risk composite score (FRCS). Distance using the FFRT for unilateral forward functional reach (UFFR) and bilateral forward functional reach (BFFR) was found then unilateral reach to height ratio (URHR) and bilateral reach to height ratio (BRHF) were calculated.

Research Analysis/Discussion: A Pearson Correlation showed UFFR, BFFR, URHR, and BRHR negatively correlated to FRCS (-0.51 to -0.54) however height correlated greater with UFFR (0.59) and BFFR (0.63) than URHR (0.42) and BRHR (0.47). An ANOVA between height group comparison showed statistical differences; UFFR (p=3.03x10^{-6}), BFFR (p=7.8x10^{-7}), URHR (p=0.00123), BRHR (p=0.00052); greater difference for BFFR than UFFR. A multilinear regression showed both BFFR and BRHR more influential to FRCS. Using a scatterplot between UFFR and BFFR, BFFR cut point values specific to height groups reduced false negatives by >60% in all height groups.

Conclusion: Height is a factor in FFRT. The extra calculation for reach to height ratio does not add improve fall risk identification. BFFR with cut points by height group, 10” for short, 11” for medium and 12” for tall, improves fall risk identification.

DEDICATION

This dissertation is dedicated first and foremost to my husband, Michael Heitzman, PhD, PE who was always there supporting me and helping me complete this work. Without his constant, calming encouragement, this work would still be a work in progress.

To my family and friends in recognition of all the time spent away from them and to encourage them to never stop dreaming and challenging themselves

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LIST OF ABBREVIATIONS

ABCs-Activities Based Confidence Scale

ADL-Activities of Daily Living

AP- anterior-posterior

ASIS-anterior sacral iliac spine

BBS-Berg balance scale

BOS-base of support

BMI-Body Mass Index

C7-cervical spine 7

CDC-Centers for Disease Control and Prevention

COG-center of gravity

COM-center of mass

COP-center of pressure

D/H-distance reach to height

EMG-electromyography

FFRT-forward functional reach test

UFFR-unilateral forward functional reach

BFFR-bilateral forward functional reach

FFRT-forward functional reach test

FRCS-Fall risk composite score

LOS-limits of stability

L1-lumbar spine 1

RHR-Reach to height ratio

URHR-unilateral reach to height ratio

BRHR-Bilateral reach to height ratio

S1-sacrel spine 1

SLS-single leg stand

STEADI-Stop elderly accident, death and injury

TUG-timed up and go

WHO-World Health Organization

CHAPTER I. Introduction

Falling has been identified as a major health threat within the aging population (Lajoie & Gallagher, 2004) not only in the United States (US), but worldwide (World Health Organization (WHO), 2007; Arai, Obuchi, Kojima, & Nishizawa, 2009). Bergen, Stevens, and Burns (2016) reported that 28.7% of people over the age of 65 fall each year and 2.8 million were treated in the emergency room with approximately 800,000 subsequently hospitalized at a cost of over $28 billion dollars. The cause for the majority of these falls is multifactorial; however, gait and balance are two of the modifiable risk factors identified by the Centers for Disease Control & Prevention (CDC) in their program "Stop Elderly Accidents, Death and Injury" (STEADI) (CDC, 2017a).

Physical therapists (PT) must make clinical decisions based on objective measures for screening and examination. Selecting appropriate tools to use with a variety of patients/clients can be challenging. While studies such as Lusardi et al. (2017) have reviewed various balance and fall risk measures (both self-reported and performance based) for predictability, little has been done to improve current measures being utilized. This chapter will discuss issues related to the Forward Functional Reach Test (FFRT), which is one test commonly used by Physical Therapists (PT). An introduction of the problem, the clinical relevance and purpose of the study, and the proposed research questions with hypotheses will be presented.

Statement of Problem

Due to the multifactorial nature of falls and the multitude of measurement tools available, identifying those at risk for falling can be challenging (Lusardi et al., 2017). Recently, Florence et al. (2018) reported that although the medical costs of both fatal and nonfatal falls in older adults has increased and though balance screenings are included as part of the Medicare Annual Wellness physical examination, most healthcare providers who participate in this program do not screen for falls. Measurement tools used in physical therapist practice to assess fall risk include performance based, self-reported, screening, and assessment measures. The variety of tests and measures available proves to be a challenge when choosing and implementing the most optimal tools to identify fall risk in older adults. Hassenkhani, Kakhki, Jafarabadi, & Malek (2012) reviewed the literature to identify the various times and aspects of various fall identification tools. They found 32 self-reporting tools on fear of falling, 48 tools on physical performance, and 25 tools on fall risk factors. Many of these tools take over 15 minutes to perform, and others were one-dimensional (Hassenkhani et al., 2012). Determining which to tool to use is difficult for the clinician based on time, cost, population, and practice setting. Physical therapists must also determine which assessment tools measure balance, have predictability for falls, or assist identifying causative factors as well as those amendable to change to make a change to a patient's quality of life.

An understanding of the difference between assessment and screening tools is important. Assessments identify whether a dysfunction exists, what underlying cause may lead to the dysfunction, and provide an in-depth look at the modifiable risk factors to identify those amendable to change in order to tailor intervention strategies (Ganz, Bao, Shekelle, & Rubenstein, 2007; Mancini & Horak, 2010). Screening tools, on the other hand, identify those at risk for falling and require a more multidimensional assessment (Chen, Gleeson, Mitchell, O'Donnell, & Olson 2013; Florida Physical Therapy Association (FPTA), n.d.). The screening process identifies risk factors related to falls based on history of falls, current presentation of a fall, or complaints of difficulty with balance or gait (American Geriatric Society (AGS), 2011). The multifactorial nature of falls requires screening of multiple systems that will identify areas requiring further in-depth assessment. These should include screenings for balance and mobility: both self-reported and performance-based measures (Kafri, Hutzler, Korsensky, & Laufer, 2017).

Of the variety of screening and assessment tools, the FFRT has been commonly used by physical therapists. The FFRT is defined as the maximum distance an individual is capable of displacing with an outstretched arm while maintaining a fixed base of support (Duncan, Studenski, Chandler, & Prescott, 1992). Forward reaching is a task that is often encountered while performing the majority of the ADLs by an older adult living independently (Row & Cavanagh, 2007). Reaching for pots on a stove, into a cabinet, getting a book or clothes from a shelf and the other components of activities of daily living skills (ADLs) require maintenance of good dynamic postural control to prevent falls (Jenkins, Johnson, Holmes, Stephenson, & Spaulding, 2010). The FFRT was developed for assessment of dynamic balance in the anterior-posterior movement and has been used as a screening measure to identify those at risk for falls (Duncan, Weiner, Chandler, & Studenski, 1990).

Duncan et al. (1990) developed the FFRT as a measure of dynamic balance, which evaluates a person's limits of stability. Limits of stability is defined as the point at which an individual can no longer maintain control of their center of mass without changing their base of support (Shumway-Cook & Woollacott, 2017 p. 162). The FFRT evaluates the maximum distance an individual is capable of displacing their center of mass with an outstretched arm while maintaining a fixed base of support (Duncan et al., 1990). The FFRT assesses postural control based on the underlying concept of maintaining anterior margin of stability while reaching, which reflects the standing dynamic balance. A greater reaching distance during the FFRT indicates better postural control (Liao & Lin, 2008).

The FFRT, which has been shown to be a valid and reliable tool, is a simple and an inexpensive measurement tool for assessing balance (Takahshi et al., 2006). Because the person is required to reach as far as possible, the FFRT has been reported as a good indicator of a person's dynamic balance in real world situations (Duncan 1990; Duncan 1992). The FFRT has shown good reproducibility over time, is sensitive to change, and the distance reached has been shown to decrease as one ages (deWaraquier-

Leroy et al., 2014). This measure only takes a few minutes to perform and identifies dysfunction of anticipatory balance in the anterior/posterior plane which makes this a tool that many therapists find beneficial to utilize.

The protocol developed by Duncan et al. (1990) instructs the individual to reach forward with one arm (dominant arm) and as long as the participant does not take a step, touch the wall, or fall, any other strategies could be utilized. Kage et al. (2009) compared 1 and 2-arm reach for the functional reach test and found the center of pressure (COP) movement was greater with 1 arm movement. Jonsson, Henriksson, and Hirschfeld (2003) utilized whole body kinematics, ground force plates, and EMG, while the participants performed a single arm forward functional reach (FFR) and found that there was low correlation between displacement of COP and FFR. They determined that the movement of the FFR was the result of large rotation of the trunk and small extension of the ankle (Jonsson et al., 2003). Thomas and Lane (2005) argued that though the studies on FFRT have been reported to differentiate those with fall history versus those without fall history, these studies were mostly done on community dwellers. Thomas and Lane (2005) therefore, focused their study on aging adults in a day hospital. They found that the FFRT did not differentiate between fallers and non-fallers in this population ($p=0.053$). There are also various reach distances reported in the literature as being predictive of falls, which makes interpreting what truly is fall risk difficult for the physical therapist (Duncan et al., 1992).

Another issue related to FFRT as developed by Duncan et al (1990) is that the participant's height in relation to the reach distance is not included in the risk assessment. Wernick-Robinson, Krebs, & Giorgetti et al. (1999) found moderate correlation between height and FFRT ($p<0.05$, r=0.63); however, they did not investigate this further. While Lin and Liao (2011) demonstrated the older adult did not reach as far as younger adults, they did not associate the reach distance with height.

Control of the center of mass (COM) in relation to the base of support (BOS) is described in research, as postural stability (Shumway-Cook & Woollacott, 2017, p. 154). Postural stability is the control of the vertical line projection through the COM relative to the BOS. The center of pressure (COP) is the center of the total force applied through to the supporting surface (Shumway-Cook & Woollacott, 2017, p. 154). This COP is constantly moving to keep the COM within the BOS and is a component of anterior displacement of COP (deWaroquier-Leroy et al., 2014). The FFRT measures anterior displacement of COM resulting in COP changes (deWaroquier-Leroy et al., 2014). Empirically, those who are taller should be able to displace their COM further anterior than those who are shorter. This would allow COP to be displaced further before risk of falling; therefore, height may have an effect on the distance one is able to reach forward. The current measure of the FFRT applies raw scores of distance reached in centimeters or inches and does not account for height.

Relevance

While the FFRT was developed as a screen for fall risk (Duncan et al., 1990), this tool has been used by physical therapists to both screen for fall risk of patients and assess balance. Due to the variations of movement patterns allowed during the test based on reaching with only one arm, the interpretation of the test results to identify fall risk may be affected by the various movement compensations. Thus, these variations may be influencing the likelihood of predicting falls. For example, someone who is allowed to use compensation while reaching with one arm (unilateral) may reach further than someone who did not use the compensation while reaching. These movement variations may be the result of underlying pathologies affecting the strength and range of motion resulting in false negatives for fall risk or a reported improvement in balance control, which is not truly present. These movement variations could also be a reason the range of results for functional reach are so large as well as the variations reported in the literature regarding the means and predictive ability for falls. The early studies by Weiner, Duncan, Chandler, and Studenski (1992) and Duncan et al. (1990;

1992) found a forward reach mean of 11.91" in 1990; however, in 1992, they found a range of 4.3"-16.5" with the mean of 10.9". Wernick-Robinson et al. (1999) found a range of 3.68" to 18.44" with the same mean of 11.9." These variations in results may be based on the various movement substitutions utilized by the individuals.

Height is another factor that has not been considered in relation to forward functional reach identifying fall risk. Heitzman, Patel, and Yu (2014) conducted a study of college age students (18-35 yrs. of age) to determine the correlation of reach to height during the FFRT. The results had a difference of average reach distance between height groups of 3.17"; with an average reach of 13.91" in the short group (those <5'5") to an average of 17.08" in the tall group (>5'9") about a 20% difference (Heitzman et al., 2014). However, when the distance reached was calculated as a percentage of the individual heights, the percentage difference was only 1.88% (Heitzman et al., 2014). By looking at these results, the distance reached for a taller person would be further than a distance reached for a shorter person. The potential result is that when taking a raw score normative cutoff for forward functional reach identifying fall risk at a distance of <10", a shorter person would be a false positive before he or she had lost much distance in reach ability, and a taller person would be a false negative until he or she had lost a large amount of distance they can reach. Clinically, using a percentage of height has the potential to identify fall risk more accurately resulting in early intervention to reduce resultant falls.

A decline to frailty and risk for falls has been identified as a reach distance of <15 cm (5.9") (Werner et al., 1992); whereas, Duncan et al. (1990; 1992) identified less than 25.4 cm (9.8") as risk for falls. The studies reviewed by Lusardi et al. (2017) also had various cut points for identification of fall risk. These ranged from ≤5.9 inches (15 cm) to ≤8.7inches (22cm) (Lusardi et al., 2017). Wernick-Robinson et al. (1999) found no difference in the mean FFRT between those with balance limitations and healthy adults. The mean of the healthy individuals was similar to the mean found by Duncan of

11.91 inches (30.25cm) (Duncan et al., 1990; Wernick-Robinson et al., 1999). However, the range found by Wernick-Robinson et al. (1999) was significantly large 3.68” (9.35cm) to 18.44” (46.85cm).

Between the compensatory movement strategies used with this one arm reach found to vary from dynamic strategies to static strategies by Wernick-Robinson et al. (1999) and the impact of the height in relation to reach as shown by Heitzman et al. (2014), the ability of the FFRT to identify true fallers is questioned. This variability may be why there is variation in cut scores and can make the identification of fall risk result in false negatives as well as false positives. Physical therapists need a simple test that is easy to administer, consistently measures the anterior displacement for balance control with forward reaching and one that is predictor of falls despite variations of height. The current FFRT procedures and interpretations does not meet this need.

Statement of Purpose

The purpose of this study was to determine if height and reach methods affect the FFRT ability to identify fall risk. A secondary purpose was to determine if a bilateral reach to height ratio (BRHR) could more accurately identify fall risk by: 1) reducing the variability of substitutions that can occur with unilateral reach, and 2) reduce the risk of false negatives/positives due to height.

Hypothesis/Research Questions

Research Questions

1. Is there a correlation between height and the FFRT distance?
2. Is there a significant difference in reach distance between three height groups when performing the FFRT with 4 different methods; unilateral FFR, bilateral FFR, unilateral reach to height ratio (RHR), and bilateral RHR?
3. What is the relationship between unilateral and bilateral arm reach when using the distance reached and the reach to height ratio in comparison to a fall risk composite score (FRCS) based on 4 other fall risk/decline to frailty tools?

4. Can a ratio be determined for bilateral RHR across all height groups that would improve the ability to identify fall risk compared to the unilateral FFR of 10" as defined by Duncan et al. (1990)?

Hypothesis

H_1: There is a correlation between height and the distance a person can reach using the FFRT

H_{2a}: There is statistical difference between 3 height groups when using the unilateral FFR and the bilateral FFR methods.

H_{2b}: There is no statistical difference between 3 height groups when using the unilateral RHR and the BRH.

H_3: Bilateral FFR will have a greater correlation to the FRCS than the unilateral FFR.

H_4: The BRHR will increase the likelihood of accurately identifying fall risk when compared to the current unilateral FFR of 10" as cut point value.

Definition of Terms

Unilateral forward functional reach (UFFR) is a term that describes the method by Duncan et al. (1990) where an individual reaches forward with one arm. Bilateral forward functional reach (BFFR) is the term used where an individual will reach forward with both arms symmetrically. The unilateral reach to height ratio (URHR) and the bilateral reach to height ratio (BRHR) identifies the percentage of the height an individual can reach under each condition. Fall risk composite score (FRCS) is a total combined score of 0-4 based on the identification of fall risk (1) and non-fall risk (0) by the outcome measures of fall history/health history, ABC, TUG, and hand grip strength.

Summary

In summary, the identification of fall risk in the aging adults is a health care concern identified by both the World Health Organization (WHO) (WHO, 2015) and the United States Center of Disease Control & Prevention (CDC) (CDC, 2016). Physical therapists must choose measurement outcomes that have a high likelihood of successfully identifying those at fall risk in order to intervene and improve outcomes. The FFRT is frequently utilized due to the small amount of inexpensive equipment, time and portability of the test. However, the variety of compensatory movements when using the unilateral reach may be limiting the ability to accurately identify fall risk. Using a cut point value of 10” without considering a patient’s height for fall risk identification may increase the number of false positives and false negatives. Modifying the FFRT to include bilateral reach and distance reached in relation to height may increase the likelihood ratio for the predictability of fall risk.

CHAPTER II. Literature Review/Background Information

Introduction

The cost of falls is increasing both on an individual and on a health care system level. Factors that underlie the fall risk in older adults will be discussed. These factors influence the choice physical therapists make regarding use of screening and assessment tools to reduce/prevent fall risk. Various tools utilized for identifying fall risk/physical decline will be introduced in relation to identification of fall risk. One tool, the Forward Functional Reach Test (FFRT), has been used since the early 1990s (Duncan et al., 1990), and controversy exists regarding usage as predictor of fall risk. A review of the literature related to use of the FFRT is discussed along with possible ways this tool could be improved. Two preliminary studies, which examined ways to improve the FFRT and the ability to identifying fall risk, are included.

Aging and Falls

The World Health Organization (WHO) identifies the aging adult as anyone over the age of 60 years (WHO, 2004). This has been further classified as young older adult (60-74), middle old (75-84), oldest old adult (≥85) (WHO, 2004). According the United States Census Bureau (2010), people over the age of 65 represented 7.1% of the US population (1 in 8) (US Census Bureau, 2010). By 2050, those over age 65 are expected to grow to 19% of the population (US Census Bureau, 2010). The increases in those over age 85 is expected grow from 5.8 million in 2010 to 19 million by 2050 an increase from 5.3% of the population to 15.1% of the population (US Census Bureau, 2010).

As the aging population increases, so do health concerns. Bayliss et al. (2014) reported 1 in 4 older Americans live with more than one ongoing medical condition. As one ages, the risk of being affected by more than one medical condition increases. The report by the CDC (2015b) indicated 65% of people over age 65 had four or more chronic health conditions. Having more than one health condition may lead to assistance with ADLs and increasing fall risk (CDC 2015b; WHO 2018). Medical costs for these multiple conditions account for 75% of US health care spending and more than 90% of Medicare spending (Bayliss et al., 2014; CDC 2017b). Due to the impact of these medical conditions on overall physical function, falling is a major concern.

Definition of fall

There is a variety of different definitions for the term "fall." Many older people describe a fall as a loss of balance, whereas health care professionals often refer to falls as events leading to injuries and ill health (WHO, 2007). Zecevic, Salmoni, Speechley, and Vandervoort (2006) conducted a survey interviewing 477 community dwelling seniors and 31 health care providers, performed a review of falls research, and consulted with fall researchers. Results showed that older adults and health care providers both focused on events that happened prior to the fall and the consequences of falling, whereas research and researchers concentrated on the overall fall risk factors and descriptions of fall event (Zecevic et al., 2006). Focusing on the consequences of the fall only provides potential to omit falls that are non-injurious, near falls, mishaps, missteps, all of which may identify the need for early intervention and participation in fall prevention programs (Zecevic et al., 2006). Falls can also be described using frequency. Peeters, Schoor, and Lips (2009) identified the occasional faller as a person that interacts with extrinsic factors and the recurrent fallers as those with intrinsic factors accompanied by an extrinsic factor two or more times within a six-month period. Noohu, Dey, and Hussain (2014, p. 31) stated recent agreement between researchers has described, "The event of a fall is when the person comes to a lower level or on the ground unintentionally". The WHO (2007, p. 1) recommended using the definition of "inadvertently coming to rest on the ground, floor or other lower level, excluding intentional change in position to rest in furniture, wall or other objects." Noohu et al. (2014) further identified a fall as one of external causes with unintentional injury. For this study, the definition by WHO (2007) of inadvertently coming to rest on a lower surface will be used, whether or not there was injury. This allows recognition of fall risk prior to injury occurring. The frequency by Peeters et al. (2009) will also be utilized to identify those that have had two or more incidents over the past six months.

Prevalence

Falling has been identified as an increasing issue and a major health risk in the aging population (Lajoie & Liao, 2004) in not only the United States, but worldwide (Arai et al., 2009). A health risk is defined by the World Health Organization as the probability that a future unwanted health event will occur; for older adults one of the health risk particularly dangerous is falling (WHO, 2004; Lusardi et al., 2017). The World Health Organization (2007) reports there is variability in incidence of falls among countries with 28-35% of people over age 65 worldwide falling each year, and this rate increases to 42% for those over the age of 75. Those over age 80 are particularly prone to falls and are the fastest growing population expected to represent 20% of the overall worldwide aging population by 2050 (WHO, 2015).

In the US, the CDC reports that one of four older adults fall each year and that only half report the fall to their primary care provider (CDC, 2016; CDC, 2018). One in five falls result in serious injury, resulting in over 2.8 million older adults treated in the emergency room at a cost of over $28 billion dollars (Bergen et al., 2016).

Cost of falls

Unintentional injuries account for 85% of deaths for those over the age of 65 in the United States with falls accounting for 55% of these unintentional injuries (Kramarow, Chen, Hedegarrd, & Waner, 2015). From 2000-2013, falls have continued to increase as a cause of death of those over age 65, with the non-Hispanic white population having the highest rate of fall deaths of 61.4 per 100,000 followed by Non-Hispanic Black (23.3 per 100,000), and Hispanic older persons (36.2 per 100,000) (Kramarow et al., 2015; Bergen et al., 2016). The United States health care system is impacted (both financially and health workers required) by these falls with over 2.8 million older people seen in the emergency room annually due to a fall (Bergen, 2016). Of these, over 800,000 people are admitted to hospitals because of fall injury, costing over $31 billion dollars in direct medical cost, with hip fracture, upper limb injuries, and head injury being the most often admitting diagnosis (Bergen et al., 2016; CDC, 2018). The CDC reports that 95% of hip fractures among those aged 65 and older are the result of falling, and the most common cause of death after a fall was complications from a hip fracture (CDC, 2015b). Peeters et al. (2009) found that 90% of all fractures of older adults were the result of falls. Hospital admissions as a consequence of falls often results in longer duration in the hospital setting as compared to other injuries, and post fall syndrome that includes dependence, loss of autonomy, confusion, immobilization, and depression leading to further decline in function in daily activities that results in increased need for healthcare (WHO, 2007). One in three older adults who lived independently prior to the fall were admitted to a nursing home for at least one-year post injury (CDC, 2015b). The United States annual Medicare cost related to falls has been estimated at approximately $31.1 billion dollars (Bergen et al., 2016). Medicaid paid $8.7 billion dollars, and private/other payers paid $12.0 billion dollars for medical care for non-fatal falls (acute and post care) with the total medical spending for fatal falls over $750 million dollars (Florence et al., 2018). This does not include the indirect cost of the fall that impacts the family and/or caregivers and the changes to the work schedule and home life (WHO, 2007).

Because of the escalating cost of falls, fall prevention is a major goal worldwide (WHO, 2015). As the number of older adult increases, falls exponentially increase with the increase age related biological changes, particularly in the over 80-year population. The WHO identified that the preventative measures for fall prevention is of major importance requiring immediate attention as falls are projected to be 100% higher by year 2030 (WHO global report, 2007; WHO world report, 2018). In the United States, Healthy People 2020 has a goal to reduce hip fractures among both male and females aged 65 and older (CDC, 2015). Florence et al. (2018) looked at the US population statistics from 2015 and concluded that preventive strategies to identify fall risk are needed to encourage interventions to reduce these risks, which could then reduce health costs.

Factors Associated With Falls in Older Adults

Factors/Indicators. Most of these falls are multifactorial but less than 50% of people who fell had ever been asked about falling by a healthcare provider (Florence et al., 2018). A panel of experts from the American Geriatric Society (AGS) and British Geriatric Society (BGS) (2011) identified multiple factors related falls such as a previous history of falling, medications, dysfunctions/limitations related to gait, balance, and mobility, presence of neurological impairments, reduced muscle strength, hypotension, and external hazards such as environment and footwear. Gait deficits and balance limitations are two of the modifiable risk factors identified by the CDC's Stop Elderly Accidents, Death and Injury (STEADI) program (CDC, 2017a).

Once a person has sustained a fall, even if not injured, there is an increased fear of falling (CDC, 2018). Actual falling and fear of falling have been shown to contribute to decreased mobility resulting in increased sedentary lifestyle. This reduced physical activity level increases functional dependence among aging adults (Smee, Anson, Waddington, & Berry, 2012). Fear of falling can lead to a reduction in everyday activities and can lead to the downward spiral of decreased physical activity. Fear of falling often leads to self-induced activity restriction and social isolation, which has the potential to diminish markedly a person's quality of life (Mancini & Horak, 2010). As shown in figure 2.1, fear of falling can lead to reduced activity (CDC, 2017a). Decreased physical activity can lead to muscle weakness, which may negatively influence walking and balance function, further reducing the physical activity. The reduced muscle activity affects one's ability to walk and maintain balance/postural control that results in a fall. Once a person as fallen, the fear of future falls increases and the cycle repeats (CDC, 2015a).

Figure 2.1: Fear of falling cycle. (CDC, 2017a)

Thus, the patient's **perceived** functional ability and fear of falls can lead to further falls (AGS, 2011; Lusardi et al., 2017).

Landers, Oscar, Sasaoka, and Vaughn (2016) studied the psychological factors that may predict future falls. Their prospective cohort study included 64 older adult participants (mean age 72.2) with a variety of medical conditions including Parkinson disease, stroke, and cardiovascular disease. The participants were measured at baseline and then contacted one-year post to record the falls that occurred during the subsequent year. Baseline measures included participants' fall history, Self-reported measures of Falls Efficacy Scale (FES) and Activities-specific Balance Confidence Scale (ABCs), and physical performance measures of Berg Balance Scale (BBS), Dynamic Gait Index (DGI), self-selected gait speed (GS), Timed Up and Go test (TUG), and the Sensory Organization Test (SOT). After one year, a multiple regression was done with all the baseline measures as potential predictors. The ABC, FES, and TUG (respectively) were found to be the most predictive of falls. These results suggest people have a better sense of their fall risk overall than a measure of balance performance at one specific moment in time (Landers et al., 2016). The only limitation to this study was the ability to remember all falls after one year. Having a daily diary may have improved the recall, but then may have also made the participants more aware of fall risks, thereby increasing their fear of falling.

The cause of falls has been associated with many factors. The WHO discusses the interaction of factors that are behavioral (medications, alcohol, inactivity), environmental (lighting, floors, stairs), socioeconomic (low education and income, limited access to healthcare and community resources), and biological (age, gender, race, illness, physical and cognitive decline) increases the risk for falling (WHO, 2007). Peeters et al. (2009) delineated the difference between fall risk and fall indicator. Risk is a causal relationship with the outcome. They utilize gait as an example; impaired gait with deviations in the gait cycle or speed is a fall risk for balance and if gait is improved, the balance will improve. A fall indicator has no causal relationship, but prevalence of falls increase with that population. Examples used were factors such as age; falls are more prevalent in older adults but age is not a cause of falls (Peeters et al., 2009).

The multifactorial nature of falls complicates the identification of those at risk for falls (Delbaere et al., 2010). The authors studied 500-community dwellers age 70-90 years and identified fallers as those who have had one fall with resultant injury or two non-injury falls within the 12-month follow-up period. They found that those with balance limitations, gait deficits, and decreased muscle strength had an increased risk for falls. Those with concerns about falling and previous history of falling increased that risk. However, those with high levels of fear of falling, independent of the physical components were related to prediction of future falls (Delbaere et al., 2010).

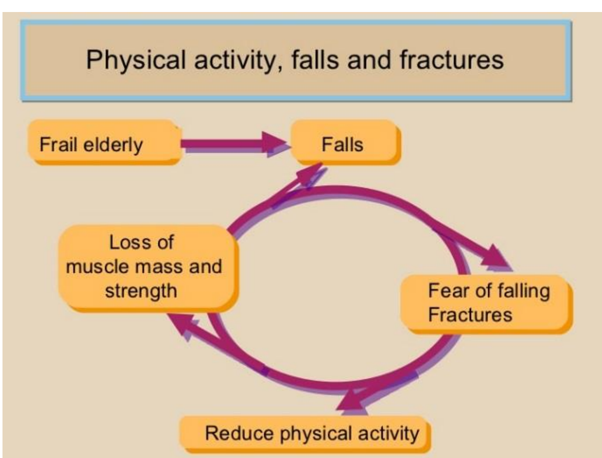
Age. The National Council on Aging (NCOA) (2015) developed the Falls Free Initiative because of the increasing prevalence of fatal and nonfatal injuries in older adults. This increase risk of falls threatens safety and independence of the older adult leading to fear of falling and limiting activity. Coleman et al. (2012) advocated “exercise as a vital sign” during their study of physical activity across the lifespan. They found that for each decade after age 60, physical inactivity doubled, leading to an increased prevalence of falls. According to the CDC brief by Kramarow et al. (2015), unintentional injuries were the eighth leading cause of death in those over age 65. Of those injuries, 55% were due to falls. They further found that people 80 years and older were 4x more likely to fall than those in their 70s and 16x more likely to fall than those in their 60s (Kramarow et al., 2015). In an editorial in the *Journal of American Medicine Association* (*JAMA*), Larson (2017) reported that fall incidence increases from age 65-80 with those over 80 more likely to move into a long term care facility following the fall. Wang et al. (2016) studied 1,092 older adults and also found that falls increase with age. Of those studied, 15.6 % of people 60-64.9 years had fallen in the past 12 months and this increased to 17.2% of those 65-69.9 years, 25.9% of those 70-74.9 years and 26.4% of those over 75 years.

Physiological Factors. Physiological factors have been identified as a factor in fall risk. These include loss of muscle strength, which leads to loss of function and frailty, intensifying fall risk with interaction with environment (WHO, 2018). Wang et al. (2016) found falls increased with depressions, diabetes, lack of spouse, and decreased muscle mass. Internal factors that impact falls include lower extremity weakness, falling in the past leading to fear of falling, and balance limitations (Hassankhani et al., 2012). The fear of falling can lead to agonist-antagonist co-contraction resulting in increased muscle stiffness leading to a fall (Zecevic et al., 2006). Falls lead to increased fear of falling, which in return amplifies the risk of fall (Duncan et al. 1990; Lord, Ward, Williams, & Strudwick, 1995; Bergland & Wyller, 2004; Noohu et al., 2014; Norris & Medley, 2011; Landers et al., 2016).

Strength. Gait, balance disorder and muscle weakness has been identified as leading causes for falls (Noohu et al., 2014). Age-related declines in muscle strength can increase the risk of falling resulting in greater loss of independence (Smee et al., 2012). Muscle force in the hip and ankle was found to correlate to the balance measures of BBS, TUG, and FFR (Daubney & Culham, 1999). A decrease in the muscle strength was more significant ($p=0.01$ and $p=0.05$ respectively) in older adults who had a history of falls. Maeda, Shamoto, Wakabayashi, and Akagi (2016) found a significant correlation ($p<0.001$) in sarcopenia with increased age leading to decrease mobility and functional decline.

Physical Activity. Older adults tend to have a decrease in physical activity possibly because of the decrease muscle activity (CDC, 2015a). Coleman et al. (2012) found only 30% of adults over the age of 18 were sufficiently active and the rate of activity decreased with age and comorbidity. Some consequences of inactivity include sarcopenia, obesity, diabetes, heart conditions, and falls as well as in some cases increased mortality. Globally, physical inactivity is known to be one of the leading cause of death and death related injuries due to falls (CDC, 2015a; WHO, 2015). The reduced physical activity is part of the cycle that leads to falls; loss of muscle strength leads to falls resulting in fear of falling, so the individual reduces physical activity more and the cycle continues. The cycles of physical activity from the CDC (Figure 2) shows the cycle of fear of falling that leads to loss of physical activity. This results in further loss of muscle mass and strength leading to further decline and falls (CDC, 2015a).

Figure 2.2: Physical Activity Cycle (CDC, 2015a)



With physical inactivity comes decreased overall standing time per day, with older adults spending less than two hours in an upright posture (van derPloeg, Chey, Korda, Banks, & Bauman, 2012). Yen, Ku, and Want (2017) studied 86 participants age 65 and older. They found that the self-reported sitting time increased as muscle strength and mobility decreased. The increased sitting time has been shown to be related to decrease mobility, increase falls and fall risk, and all-cause mortality (van derPloeg et al., 2012).

Balance. The correlation of strength to balance has been well documented. Muir, Berg, Chesworth, Klar, and Speechley (2010b) performed a systematic review of prospective studies of at least one-year duration. They found balance limitations had a significant association with those that sustained a fall. Of those who fell, 74% also had a resultant strength deficit (Muir et al., 2010b).

Bergland and Wyller (2004) studied falls in elderly women living at home and discovered balance impairment is one of the most common contributing risk factors. According to Zecevic et al. (2006), loss of balance and motor control were the two highest causes of falls identified by both seniors and health care providers with the older adult more frequently associating falls with loss of balance. In this same survey, the researchers, on the other hand, identified muscle weakness as the highest factor (Zecevic et al., 2006). Vestibular function is a component of balance (Shumway-Cook & Woollacott, 2017, p. 281-282) and has been shown to decline with age (p. 369). Olsson Moller, Kristensson, Midloy, and Jacobsson (2012) found that complaints of dizziness more than doubled in people over the age of 80. These complaints were associated with increased balance limitations, fear of falling, decrease grip strength, and dependence in basic and instrumental activities of daily living (Olsson Moller et al., 2012).

Physical Function. Smee et al. (2012) studied the comparison of physiological changes with aging and physical function to determine the relationship between physical function and fall risk. By using self-reported scales, fall history, and functional tasks of everyday lifting and movement, they found that increasing age and decrease in physical function increased fall risk and deterioration in performing daily activities (Smee et al., 2012). The authors showed while decline occurs with aging, people are able to self-assess realistically their own level of physical function and that by improving the physical function, independence can be returned with reduction in fall risk (Smee et al., 2012). Aria et al. (2009) performed an intervention study of aging adults in Japan and found that TUG, Grip strength, and FFRT (these tools will be discussed in depth later) all improved with exercise intervention. The result supports the idea that early identification of functional decline along with intervention to improve physical activity has the potential to reduce the fall statistics (Aria et al., 2009).

Balance Control. Aging is accompanied by decreased balance control with approximately 75% of people 70 years and older presenting with balance limitations (Kafri et al., 2017). Deficits in postural control (which impacts balance) can lead to falls and limitations in activities (Noohu et al., 2014). The STEADI program of the CDC identifies balance and gait as modifiable factors (CDC, 2017a); therefore, if balance is identified as a risk factor of falls early, interventions can be implemented to assist in reducing the prevalence of falls. To achieve this goal, an understanding of balance is an important aspect of selecting the appropriate screening and assessment tools for providing healthcare to the older adult.

Balance is a complex multisystem activity that is defined as the "ability to control the center of mass over the base of support, within the limits of stability" in a given sensory environment (Mancini & Horak, 2010, p. 1). Balance control/postural control has been determined to be essential for mobility as well as stability in functional activities (Noohu et al., 2014). The interaction required between multiple systems (visual, vestibular, and cognitive) has motor related implications (Kafri et al., 2017; Shumway-Cook & Woollacott, 2017 p. 281-282). Balance control is required in daily activities that require the movement of the center of mass over the base of support and inadequate control impacts the limits of stability, which may be one of the problems with falling (Shumway-Cook &Woollacott, 2017, p. 154).

Deficits in muscle strength, sensory function and speed of response all occur with aging resulting in variations in balance strategies, which affect this control (Mancini & Horak, 2010). Loss of balance has been identified as the most common contributing factor of falls in aging adults (Bergland & Wyller, 2004; CDC, 2017b). A meta-analysis by Muir et al. (2010b) linked balance impairment to an increase fall risk in community dwelling older adults.

Maintaining balance by reaching through various angles of stability requires effective control of center of gravity (COG) with relation to their BOS (Clark, Iltis, Anthony, & Toews, 2005). Declines with control of COG, reduced postural limits and/or limitation in movement result in risk of falls while performing activities (Clark et al., 2005).

Huang (2009) and Huang and Brown (2013) compared 14 young adults (aged 20 $\pm$ 1.5 yrs.) to 16 older adults (73.4 $\pm$ 5.3 yrs.) in relation to posture control as measured through the center of pressure (COP) and anticipatory postural adjustments (APA) while reaching at targets of various heights. The smoothness of the trajectory of the COP decreased with age and with the lower targets. The results indicated that while older adults may alter their APA, the control of COP during movement is compromised with aging having implications for the assessment of balance and development of training programs (Huang, 2009; Huang & Brown, 2013). While this study includes equal numbers of both young and old and measured, various height targets comparable to daily activities individual height was not a measurement used for comparison.

Comorbidities and age-related muscle changes have a significant effect on the elderly ability to displace their COP, which could be a factor that plays a significant role in falls (Cavanaugh et al., 1999; Liao & Linn, 2008). Cavanaugh et al. (1999) demonstrated that the elderly are less likely to shift their COP to the limits of their stability, especially in the sagittal plane. The FFRT measures the limits of stability in this sagittal plane and this impact on the center of pressure may be the underlying issue related to compensations with the unilateral reach.

Measuring Balance and Fall Risk

The American Geriatrics Society (AGS, 2010) has recommended guidelines for screening and assessment of the aging adult concerning fall that includes balance testing and strength testing. These were updated in 2011 and includes asking regarding fall history and performing screens for balance, strength and gait (AGS/BGS, 2011). Any person who performs poorly on a standardized gait, strength, or balance-screening test should be referred for a multifactorial fall risk assessment (AGS, 2010; AGS/BGS 2011). However, accurately identifying those who could benefit from the multifactorial assessment is challenging for the physical therapist and other health care professionals due to the multifactorial nature of falls and the abundance of measures being used in research and practice (Lusardi et al., 2017).

Challenges

Hassenkhani et al. (2012) performed a literature review to identify the various times and aspects of various fall identification tools. They found 32 self-reporting tools on fear of falling, 48 tools on physical performance and 25 tools on fall risk factors. Many of these tools take over 15 minutes to perform, and others were mono-dimensional (Hassankhani et al., 2012). Choosing which tool to use is difficult for the clinician bases on time, cost, and population assessed, as well as setting of assessment. Many tools have been developed for specific populations as a tool used for predictive ability, evaluative needs, and/or development of interventions. An understanding of why a tool was developed and what populations the tool has been validated for is important when making a decision for usage.

Screening tools should be easy to administer requiring little time or equipment and be able to identify an impairment that is associated with fall risk in order to refer for further assessment.

Measurement tools should be used to quantify the components of the impairment (Muir et al., 2010a; Florence et al., 2018). Determining which screening tools are able to most identify those patients that need the multidimensional fall risk assessment can be a problem for the clinician (Lusardi et al., 2017).

Another challenge is that most studies have been retrospective at identifying falls (Lusardi et al., 2017). This does not reduce the prevalence of fall nor provide avenues for intervention before a fall occurs. The combination of retrospective and predictive tools may be the best evidence in reducing future falls. When predicting falls, having a fall within the next 6 months is sufficient for identification of fall risk (Lusardi et al., 2017). However, with the high number of tools available, determining which most predictive, time efficient are and ease of use on a variety of populations and settings can be difficult for the clinician.

Self-Reporting Measures/Performance Based Measures

The multiple interactions that impact balance requires a multiple multidimensional assessment of both self-reported and performances based measures (Kafri et al., 2017). Muir et al. (2010a) performed a prospective study to compare the individual components of the Berg Balance Scale (BBS) and a self-reported questionnaire on balance impairments to predict falls. Out of 182 participants, 43 were identified as fallers based on the limits of stability test (forward reach item of the BBS) of <10". Any individual who answered yes to any of the questions regarding falling were identified as a faller with 53 identified as fallers. During the one-year follow-up period where the participants had kept a daily log of falls and submitted monthly, for the limits of stability, 24/43 had actually fallen and 19/43 were non-fallers resulting in absolute fall risk of 56% accuracy. The self-reported questionnaire of dizziness, lightheadedness, loss of balance identified 30/53 had actual fallen, and 23/53 were non-fallers for an absolute fall risk of 57% (Muir et al., 2010a). The authors stated that the self-report of balance limitations appears to be an important component of fall risk assessment in identifying future falls (Muir et al., 2010a). The limitations was the use of a questionnaire based on history of symptoms and falls, not a standardized self-reported measure.

Lusardi et al. (2017) discussed the contribution that fear of falling has on the perceived risk for falling and thus individuals reducing their physical activity based on this perceived risk and may have clinical utility for screening. However, this intense systematic review/meta-analysis showed that the performance-based measures were stronger in predicting fall risk than the self-reported measures (Lusardi et al., 2017).

Performance based tests have been developed for assessment of physical factors related to falls. Threshold values have been utilized to identify those at high risk for disability as well as screening for deficits in daily activities; thus impact risk for decline in function. Each of these performance-based tools comes with their own advantages and disadvantage (Mancini & Horak, 2010). Berg Balance Scale, for example, focusses on balance in multiple aspects of balance conditions such as fixed position, dynamic movement over fixed base, and limits of stability. All 14 items are anticipatory with no reactive balance condition (Berg, Wood-Dauphinee, Williams, & Gayton, 1989b).

Self-reported questionnaires, on the other hand, are frequently administered and focus on behaviors that are clinically relevant to the need for caregiving. Landers et al. (2016) concluded balance confidence and fear of falling were most predictive of falls in older adults. However, there has been concern, that these self-reported physical function assessments provides insufficient information on the type of deficit and lacks sensitivity to changes in severity as well as being biased by environment, culture and attitudes and unlikely to identify early impairments (Goldman, Glei, Rosero-Bixby, & Weinstein, 2014).

Goldman et al. (2014) discussed the consensus among health providers is that performance based measures are considered to have greater face validity and more sensitive to change. Performance measures are also thought to capture physical function changes in early impairment and have a greater predictive value than self-reported tools. To test this assumption, Goldman et al. (2014) performed a longitudinal study of 3409 older adults across two countries, aged 53 and older to compare various performance based measures (gait speed, grip strength, pulmonary function, and sit to stand) with self-reported measures of ADL function. Using a Receiver Operator Characteristic (ROC) curves found that over a five-year period, though performance based measures identified subtle variations of physical capability, the predictability of functional decline was not significantly different between performance based and self-reported. The results suggested that adding self-reported measures to at least two performance-based measures appear to be better predictors of functional decline (Goldman et al., 2014). While the results were similar across both countries, some participants were unable to perform one or more of the outcome measures based on safety, inability, or willingness ranging from 2.8% of the population to 11.7%. As the study was done in various locations including participants' homes, variances in procedures occurred. These variables in test performances included: gait speed being done on 2-2.5m distance versus 6 m based on space, grip strength only done on one side instead of maximum of both, and one trial instead of two in several cases. These inconsistencies could have affected outcome results. There was also a large attrition rate due to failure to return for follow-up or death (739) for an attrition rate of 27%.The self-reported questions were based on ADLs and mobility limitations as questions and not a standardized measure.

Utilizing tools that assess risk factors, physical performance and fear of falling were found most successful in identifying fall risk in older adults (Hassankhani et al., 2012). Lajoie and Gallagher (2004) supported this statement by comparing postural sway and reaction time between fallers and non-fallers. The results showed that BBS and ABCs total scores contributed to prediction of falls thus indicating the multifaceted of fall risk assessment (Lajoie & Gallagher, 2004). Landers et al. (2016) also found that adding the Timed up and Go (TUG) to the assessment increased the predictability of falls in older adults.

Physical performance has been linked to functional decline in areas of mobility, balance, strength, and exercise capacity and should be considered in screenings and assessments (Brooks, Davis, & Naglie, 2006). Tasks can be timed, reflective of daily tasks, ranked on ordinal or Likert scales, and be screening tools or multidimensional assessments. An important outcome from performing these tasks is independence, reduce falls, and increase functional ability (Brooks et al., 2006).

Determining which tool to use in which setting and which populations can be a challenge given time constraints, feasibility and predictability of each test. Clinicians must determine which performance measures to utilize within the various clinical settings and the various patient populations in order to develop the most effective and efficient patient plan of care (Brooks et al., 2006). With the increase in falls in aging adults, accurately identifying those requiring interventions to reduce fall risk is challenging (Lusardi et al., 2017). Functional balance tests are used by clinicians to document current status and progress from interventions (Mancini & Horak, 2010). The majority of falls in the older adult occur during locomotor activities yet performance on non-locomotor balance activities are used to identify fall risk (Wernick-Robinson et al., 1999) adding to the clinician's dilemma.

Lusardi et al. (2017) undertook the challenge to identify the posttest probability of over 119 fall risk tools. They were unable to calculate the posttest probability of falls for 63 of these tests. With utilizing a fall risk pretest odds of 30% (calculated based on prevalence for community living older adults) and calculating the likelihood ratio utilizing the sensitivity and specificity of the test, comparison of the posttest probability of falls was determined (Lusardi et al., 2017). For the functional reach test, the positive likelihood ratio of identifying fall risk was found to be +7.9; the negative likelihood ratio was only -0.5 with a cutoff of 22 cm (8.7") (Lusardi et al., 2017). However, upon reviewing the study by

Lusardi et al. (2017), only 2 articles on FFRT were included, a prospective study which had a cutoff of 15 cm (5.9") and a retrospective study which had the cutoff of 22 cm (8.7"). This indicates that the predictive ability of the current FFRT is questionable for identifying fall risk and may need modification that considers the variations of movement strategies and impact of height.

Review of Selected Balance Tools

Functional balance tests are used to document current status and progress from interventions (Mancini & Horak, 2010). The majority of falls in the older adult occur during locomotor activities yet performance on non-locomotor balance activities are used to predict falls (Wernick-Robinson et al., 1999). With the multitude of measures addressing balance, selecting the tools to utilize was based on the physiological changes in muscle function and postural control of COM within BOS that impact falls, the need for additional self-reported measures, and a mobility balance measure.

Multidimensional Tools

Many multidimensional tests can be utilized in full assessment but can take 15-30 minutes to perform. Two commonly used tools will be discussed with pros and cons for usage.

Berg Balance Scale. The Berg Balance Scale (BBS) (Berg, 1989a; Berg et al., 1989b) is a multidimensional test. The purpose is to evaluate static and dynamic balance through observation of commonly performed tasks of mobility. However, the BBS only assesses anticipatory balance and not reactive balance; a condition commonly found in daily activities. The BBS measures neither the quality of gait nor the speed of walking; the BBS may be less useful when motor control is the bigger contributor to balance dysfunction than muscle weakness (Downs, Marquez, & Chiarelli, 2013).

The BBS can take 15-20 minutes to perform and has been shown to have good specificity (96%) but has had reported poor sensitivity (55%) (Mancini et al., 2010). However, Lajoie et al. (2004)

reported a sensitivity of 89% for prediction of falls in older adults. Lusardi et al. (2017) calculated the posttest probability at 59% with a score of < 50/56.

The scoring for the BBS is done on an ordinal scale with score of less than or equal to 49 being at high risk for falls and for those between 49 and 56 for each 1 point drop in score, fall risk increases 6-8% (Noohu et al., 2014). Muir et al. (2010) interpreted the BBS for low fall risk (48-56), medium fall risk (40-47), and high fall risk (≤39). However, they also found that scores of <44 increases the risk for multiple falls. The BBS has been studied with patients with various conditions such as Multiple sclerosis, chronic obstructive pulmonary disease, Parkinson disease, stroke as well as community and frail older adults. Each of these conditions have different cut scores. Neuls et al. (2011) performed a systematic review, found varied cut point scores, and varied clinometric values. These authors suggested that the BBS is not useful for predicting falls in older adults with or without pathology. They went on to recommend that this scale is best used for individual assessment of balance function and should be used in conjunction with other measures based on the patient's unique factors (Neuls et al., 2011).

Due to the variability of conditions, there is also difficulty in identifying the clinical significant change in function especially among those at the highest risk of falls (<36/56) (Mancini & Horak, 2010). Downs et al. (2013) performed a systematic review and found the minimal detectable change (MDC) to vary between 2.8 and 6.6 points, with the absolute reliability stronger at the higher points of the scale and weaker towards the middle of the scale. Donoghue et al. (2009) determined that the MDC varies depending upon the continuum of points scored at the initial BBS assessment. These variations can be 3.3 points if in the upper scores (45-56), 6.3 in the range of 25-34 points, and 4.6 if less than 24 points (Donoghue et al., 2013).

These variations in cut scores for fall risk and MDC make the BBS more of an assessment tool versus a screening tool. The BBS has a ceiling effect for those < than 75 yrs. without a specific health condition (Downs et al., 2013). This ceiling effect, along with the time required for performance of the BBS, limits the use of this measure to clinic assessment and not for identifying fall risk in a community screen event.

Interesting is the BBS component for the forward reach uses bilateral arm reach to avoid trunk rotation (Berg et al. 1989a & Berg et al. 1989b). This is different than the unilateral FFR per Duncan et al. (1990). However, using the ordinal rating of 0-4, the Berg requires 10” or greater to be considered at no risk for a score of 4, 5” or greater for a 3, 2” or greater for a score of 2, less than 2” for a score of 1 or with assistance for score of 0 (Berg et al., 1989a). Duncan et al. (1992) used the unilateral and determined 9.8” as fall risk and Werner et al. (1992) identified 5.9” as the cut for frailty. These differences may be due to the reach method of unilateral or bilateral.

Performance Oriented Mobility Assessment. The Performance Oriented Mobility Assessment (POMA) is the oldest and widest used among older adults and has a separate component for balance and gait (Tinetti, 1986; Yelnik & Bonan, 2008). Though there is good inter rater reliability and excellent sensitivity (93%), many items are difficulty to assess on the 3 point scale; there is poor specificity (11%) and the gait section has a ceiling effect (Yelnik & Bonan, 2008). The posttest probability of falling was determined to be <25/28 and the posttest probability was only 42% (Lusardi et al., 2017). The POMA has more often been used as a screening tool for, either balance or gait, as a result of these clinometric (Mancini & Horak, 2010). Lin et al. (2004) compared the balance portion of the POMA with the TUG, FR, and single leg stand (SLS) in community-dwellers. The POMA was more useful in predicting decline in ADL function versus fall risk for community-dwellers (Lin et al., 2004). With the multitude of tasks, the time required for a community screen the POMA has limited efficacy of usage in screening events. This tool is more used as part of an assessment of an individual' and not a predictor of fall future fall risk.

Screening Tools

Other multidimensional assessment tools for assessing balance and gait are available, but with the time and equipment needed, these may not be appropriate for a screening tool. The sole purpose of screening is to identify those at risk for falling in order to refer for a more multifactorial assessment. The American Geriatrics Society (AGS) has guidelines for screening of the aging adult concerning fall risk (AGS, 2010). This includes asking about fall history and performing screens for balance, strength and gait (AGS, 2010; AGS & BGS, 2011). The Medicare Wellness Screening also includes screening for fall risk (Florence et al., 2018). Any person who performs poorly on a standardized gait, strength or balance screening test should be referred for a multifactorial fall risk assessment (AGS, 2010; AGS & BGS, 2011).

With limited time in a clinic, the therapist needs tools that are time sensitive in screening patients to determine who requires a full assessment. As per the AGS, gait, strength and balance screening should be done on all aging adults (AGS, 2010; AGS/BGS, 2011). To compare the methods of the FFRT, other screening tools will be reviewed for comparison to the methods for this study. These will include a tool for gait/mobility, strength, and a self-reported measure to ensure that the components identified by the AGS guidelines that affect balance are included.

Timed Up And Go. The Timed Up and Go (TUG) is recommended by the AGS as a screening and assessment tool of fall risk according to their algorithm (AGS & BGS, 2011). The TUG along with the Sit to Stand Test and 4-stage balance test are tools recommended by STEADI for identifying fall risk (CDC, 2017a). TUG has been shown as a valid and responsive outcome measure for patients in inpatient geriatric rehab programs (Brooks et al., 2006). Brooks et al. (2006) compared TUG to the functional independence measure (FIM) and found TUG correlates with function in determining outcome as well as predicting future needs.

The Timed Up and Go (Podsiadlo & Richardson, 1991) is easy to perform in any setting taking only three minutes to perform, and inexpensively relies on stopwatch versus a rating scale (Mancini & Horak, 2010). The TUG is a test of basic functional mobility (Shumway-Cook, Brauer, & Woollacott, 2000; Noohu et al., 2014) and has been standardized across settings (Shumway-Cook et al., 2000; Bohannon, 2006) and populations (Whitney & Marchetti, 2004; Andersson, Kamwendo, Seiger, & Appelros, 2006; Dibble & Lange, 2006; Nemmers & Miller, 2008). Ayan, Cancela, Gutierrez, and Prieto (2013) found the TUG to be a good measure for institutionalized older adults reporting this was a measure of functional independence not influenced by co morbidities or cognitive changes. Lin et al. (2004) discovered good correlation between TUG and SLS for community dwellers in identifying balance dysfunction. This makes TUG a measure that can be used in multiple settings and populations as a measure of functional fall risk.

The TUG test is a functional screening tool that measures the time taken to rise from a chair, walk three meters, turn around, walk back to the chair, and sit down (Podsiadlo & Richardson, 1991). Success in safely completing the test and the time to complete test assists in determining an individual's risk of falls as results are compared to the established normative values. The TUG has been shown to predict falls in aging adults (Mancini & Horak, 2010) and has been found to have a sensitive (87%) and specific (87%) measure for identifying those who are prone to falls as well as correlates well with assessment that is more detailed measures (Salzman, 2010). Savva et al. (2013) studied 8,175 older adults comparing various outcome measures, which identify decline in function leading to frailty and falls. TUG was found to identify those at high risk of decline and falls with 93% specificity at 10 seconds (Savva et al., 2013).

There is controversy regarding what time to complete the TUG is indicative of fall risk. Bohannon and Schaubert (2006) and Lusardi (2003) performed an analysis of predictability and determined that completion of this test in greater than or equal to 13.5 seconds is indicative of high fall risk in community dwelling adult. Bohannon (2006) also performed a meta-analysis that included 21 studies comprising 4395 participants. There was great diversity amongst these studies in populations as well in the methods of performing the TUG. Some studies had the participants walk at a comfortable speed, some quickly; some had them walk one practice, one timed versus two timed. Some took the best score; some began the time on the word "go," and some when the person began to move. Some averaged the score, and some had them walk to a line and some around the cone. Overall, the mean score was 9.4 sec with a Confidence Interval of 8.9-9.9 sec. These were broken down by age groups of 60-69 (8.1 s), 70-79 (9.2s), and >80 (11.3 s). With using the upper limits of the Confidence Interval for each group (9,10.2, 12.7 seconds respectively), Bohannon (2016) recommended that anyone who took longer than these upper limits should be referred for balance assessment as may be an early sign of fall risk.

More recently, Wang et al. (2016) studied 1092 older adults to determine the relationship of TUG in identifying fall risk. They excluded anyone who required assistance to complete the TUG, those with visual impairments and those who took medications that were known to have side effects of falls. The average age of the participants was 67.35 $\pm$ 5.93 yrs. The definition of falls used in this study was "any event that resulted in inadvertently landing on the ground or lower level excluding those related to violence, or medical conditions such as seizure, loss of consciousness, paralysis" (Wang, 2016). Utilizing chi-square tests and receiver operating characteristics curve, the results indicated that the cutoff for TUG time for fall is 9.71 sec with area under the curve (AUC) 0.609. This cutoff TUG time increased with age: 9.05s for 60-64.9 years, 9.77 s for 65-8=69.9 years, 9.96 s for 70-74.9 years, and 10.86 s for those 75 and older (Wang, 2016). Overall, the researchers determined that the longer one took with performing the TUG, the higher the risk for falls.

However, in a more recent in-depth systematic review with posttest probability, Lusardi et al. (2017) found that the TUG of greater than 12 seconds had a posttest probability of fall risk (falling in the next 6 months) of 47%. This finding was based on review of 12 prospective and retrospective studies for a combined investigation of 6410 older adults (Lusardi et al., 2017).

After reviewing this literature, there is variation in what the cut point score is for fall risk. These times range from 9.77 to 13 .5 seconds. Some of the variances could be the defining of high risk versus a fall within the next 6 months. Since AGS recommends gait screening for aging adults, TUG fits the time constraints as is easy to perform with minimal equipment, space and time. However, one must determine which cutoff will be used based on the setting this tool is utilized. For this study, the most recent criteria of 9.05s for those age 60-64.9 yrs., 9.77 s for 65-8=69.9 years, 9.96 s for 70-74.9 years and 10.86 s for those 75 and older based on Wang's study will be utilized (Wang et al., 2016). This is due to the inclusion criteria being clearly described of those requiring assistance to perform the test and the definition of fall being any inadvertently landing on a lower surface or ground excluding a violent activity, medication or seizures (Wang et al., 2016).

Activities-Specific Balance Confidence Scale. Self-efficacy refers to the perception of one's ability to do tasks, in this case perform activities without loss of balance or falling (Kafri et al., 2017). Balance confidence is related to fear of falling and has been seen as a barrier to function, increasing risk of falling (Kafri et al., 2017). Mehdizadeh et al. (2016) studied 139 participants with an average of 60.2 yrs. (SD 12.27) and found that all dimensions of quality of life were significantly impacted by the intensity of fear of falling. Landers et al. (2016) performed a prospective analysis, which included 64 participants aged 72.2 years (SD 7.2) with and without pathology. Those with pathologies included cerebral vascular accident, diabetes, Parkinson disease, and cardiovascular diagnoses. The participants completed fall history, performance based measures of BBS, TUG, gait speed, dynamic gait index, and sensory organization test along with the ABC and fear avoidance behavior questionnaire. After one-year, the participants were contacted regarding falls during that period. Landers et al. (2016) used a multiple regression and determined balance confidence and fear of falling were most predictive of actual falling, 38% and 5.6% percent respectively with TUG being the next variance of significance across all the populations (Landers et al., 2006).

Grimbergen Schrag, Mazibrada, Borm, Bloem, et al. (2013) examined the impact of falls, fall history, consequences of falls, balance confidence and fear of falling in relation to the objective measure of balance using POMA for 74 individuals with Parkinson disease. The Parkinson disease Quality of Life was assessed, and patients were examined using the United Parkinson disease Rating Scale (UPDRS) and POMA along with the falls questionnaire, fall history, balance confidence and fear of falling self-reported measure. The disease severity was found to account for 43% of the differences in the quality of life. A standardized regression was performed to determine how fear of falling, balance confidence, and fall frequency impacted this. Standard regression coefficients were calculated and found 0.34 for fear of falling, 0.28 balance confidence, and 0.13 fall frequency. They concluded that fear of falling impacts quality of life and needs to be included in all balance screens (Grimbergen et al., 2013).

Norris and Medley (2011) compared those with high balance confidence to those with low balance confidence. They utilized four reaching situations including FFR, FFR on foam, and reaching to an object that was moved further and further away until maximum reach obtained both while on foam and while on firm surface. Their results showed that those with high balance confidence performed better than those with low balance confidence in all activities indicating that self-assessment of balance correlates to function (Norris & Medley, 2011).

However, self-reports have been criticized as being biased by multiple factors that include environment, culture, attitudes that may be difficult to identify early stages of impairment. Melzer, Tom, Lan, and Guralnik, (2005) compared the self-reported data from participants in two major studies: NHANES III and the LASA. The NHANES III was done between 1988-1994 with people age 60 or older and included 6596 individuals across the United States, and the LASA was a longitudinal study of 3107 people aged 60 and over from the Netherlands. Based on criteria needed regarding self- reported information, Melzer et al. were able to include 5531 from the NHANES III and 2115 from the LASA studies. With comparing sociodemographic variables of gender, age, race, income and educational level, they discovered significant differences between each of these categories ($p<0.0001$) when comparing self- reported disability with performance based measures. Melzer et al. (2005) found that reporting of disability was greater in women than men; White Americans than non-White; higher income and education than lower income and education; and variances based on geographic location. However, this study utilized data from two previous studies (NHANES III and LASA) that were based on interviews with questions developed for both those studies and not standard self-reported test measures such as the ABCs.

The Activities Based Confidence (ABC) Scale is a self-reported questionnaire used to measure an individual's confidence in performing 16 various activities (Powell & Myers1995) and assess the participant’s fear of falling or experiencing unsteadiness with daily activities (Mancini & Horak, 2010). Powell and Myers (1995) examined the psychometrics of the ABC and determined that the ABC scale is suitable to detect loss of balance confidence in highly functioning seniors, was an efficient discriminator between fallers and non-fallers, and demonstrated good test-retest reliability, convergent and criterion validity. Higher score indicates greater confidence to perform activities without falling with scores below 67% indicate a risk for falling and can accurately classify people who fall 84% of the time with an 89% sensitivity and 96% specificity (Lajorie & Gallagher, 2004).

However, in the large systematic review of articles addressing falls, Lusardi et al. (2017) identified the early fall risk as a score of <90% with a posttest probability of 59%. The problem with this systematic review was that though the entire study was based on 59 studies, only one article on ABC was included. That study was a retrospective study with only 115 participants; 34 had a fall and 81 did not (Lusardi et al., 2017).

Kafri et al. (2017) studied 45 residents of a geriatric center with a mean age of 90 yrs. (± 3.7 yrs.) and discovered those who had reported at least one fall had a significant lower self-confidence as indicated by the ABC than those who did not fall in the previous year. The ABCs was also found to be a significant predictor of falls (p=0.0009) (Kafri et al., 2017).

Utilizing a cutoff of 67% on the ABC in fallers, Reelick, van Iersel, Kessels, and Rikkert (2009) found that gait speed decreased and variability of stride length and cadence increased with those who had a fear of falling. They concluded that various adaptations for gait occurred because of fear of falling that could lead to fall risk (Reelick et al., 2009). There is also excellent correlation documented between ABC score and the TUG test (Lusardi, 2003; Bohannon, 2005; AGS & BGS, 2011).

Based on this literature review, a person's perception of his or her balance has been shown to be indicative of gait changes and reduction of physical activity which impacts overall functional decline as previously discussed. While Lusardi et al. (2017) identified <90% on the ABC indicates early fall risk, the posttest probability was only 59%. This higher score may identify those with fear of falling but has not translated to prediction of falls in almost half the population. Therefore, for this study, <67% will be utilized for identification of fall risk based on the changes in physical function as described in the literature.

Strength Testing: Handgrip. Decrease in muscle strength has been identified as a fall risk factor (Delbaere et al, 2010; Florence et al., 2018). Handgrip has been shown to correlate with other muscle group strength and therefore is an estimate of the overall strength of the individual (Silventoinen et al., 2008). Bohannon (2015) reviewed eight large sample studies and reported that low grip strength was consistent with longer hospital stays, increased risks of complications while in the hospital, the development of disabilities, decrease in physical function, and premature mortality.

Dynamically measured grip strength is a simple and affordable screen with predictable validity. Grip strength is a vital tool used to screen aging adults as a marker of physical decline, (Syddall et al., 2003) predictive of future physical decline, (Bohannon, 2008), and has been used as a measurement of both upper body and total body strength (Goldman et al., 2014). Decrease physical function has already been discussed as a physiological factor impacting balance and falls indicating need for strength testing in older adults. Grip strength is an easy method for screening overall muscle function. Grip strength testing has also been included as part of the AGS recommendation as a screening and assessment tool of fall risk according to their algorithm (AGS & BGS, 2011). Strength can be screened in a variety of functional methods including the sit to stand test as per the STEADI (CDC, 2017a) or the handgrip dynamometer as per the National institute of Health Toolbox (Healthmeasures, 2018). For this study, the handgrip dynamometer was chosen to reduce the time in an upright position that may lead to greater fatigue of the participants.

Decreased grip strength is associated with physical decline, suggesting that volitional muscle strength can be a cause as well because of physical disability (Massy-Westropp, Gill, Taylor, Bohannon, & Hill, 2011). Grip strength has been correlated to overall muscle mass, strength, and measure of function, health status, and predictor of physical function (Syddall et al., 2003). Bohannon (2008) undertook a meta-analysis evaluating 45 research articles on grip strength in middle and older aged adults. He discovered that low grip strength was consistently associated with decline in overall function leading to disability and premature mortality. His resultant recommendation based on this meta-analysis was grip strength is a useful screening tool for early identification of decline (Bohannon, 2008).

Goldman et al. (2014) performed a five-year longitudinal study that included 2290 older adults aged 53 and older across two countries regarding self-reported scales, grip strength, gait speed and sit to stand. The mean grip strength was similar between the two countries at 27.3 and 28.2 kg. Using a receiver operative characteristic curve to determine the measure of discrimination and probability of decline based on each measure to the five-year result, grip strength was more predictive than the other performance measures (Goldman et al. 2014). The results showed that in the presence of self-reported limitations based on five ADLs (bathing, eating, toileting, moving around the house, and getting out of bed) rated as difficulty or not with zero being no difficulty for a total self-reported limitation of 5. Grip strength was more significantly associated with decline, especially early decline, than the gait speed and sit to stand tests. The weak muscle strength (as indicated by the stronger of two trials) may increase a susceptibility of an individual to injury and reflects overall muscle strength. Those unable to perform at least 20 Kg of grip strength have predictive probability of a 56% increase risk of physical decline that results in injury and death (Goldman 2014). While grip strength does require specialized equipment, the ease of performance can be done in any setting with no need to adjust for differences in chair height as in the sit to stand. Limitations included the large attrition rate of 27% due to failure to return for follow-up or death (739) and variations in performing the grip strength (1 trial versus 2, one side versus both) and distances for gait speed based location of testing (in home versus clinic).

Handgrip measurement has been recommended by the AGS as determinant of functional decline that leads to fall risk and an indicator of risk for disability since 2010 (AGS, 2010). Sallilnen et al. (2010) performed a cross sectional analysis on 1084 men and 1562 women age 55 and older comparing gait speed to grip strength and determined that screening for grip strength correlates to mobility limitations. Yorke, Curtis, Shoemaker, and Vangsnes (2015) stratified grip strength values by age, gender, and chronic disease. Bohannon (2015) identified the criterion for function requires a grip strength of 18.5 kg (40.97lbs) for daily tasks in aging adults. His review further identified that grip strength cutoff for predicting functional decline for males was 26kg and for females 16kg (Bohannon, 2015).

Wang et al. (2018) examined grip strength as a predictor of fall risk since grip strength has been shown to correlate with muscle strength of lower extremities and lower extremity strength associated with fall risk. They utilized the stronger of two trials of the dominant hand for the analysis. To adjust for the variance in body size to ensure evaluation of muscle strength independent of body size, the grip strength was divided by body weight (kg). The results showed that grip strength declines with increased fall risk. Utilizing chi square and receiver operating characteristic curve (ROC), the cutoff for fall risk was determined. The cutoff point for falls based on grip strength was found to be 0.3816 (38% of the individual weight of the participant) and the AUC was 0.594 (Wang et al., 2016).

Massy-Westropp et al. (2011) investigated the relationship of handgrip strength with body mass index (BMI) through a longitudinal study of over 2988 participants (about 50% men and women equally). Following exclusion criteria based on upper extremity injury or pain, the remaining participants included 2629 between ages of 20 and 75 years. The participants under age 40 were 41.5% of the population studies. The mean BMI was 28.1(± 5.5) with a range of 14.6-60.1). The grip strength was measured for three trials of each side with elbow at the side at a 90-degree angle and forearm positioned in a neutral position resting on a table. The mean was recorded for each hand. The participants were divided into groups based on decade of age for a total of six groups. There was a weak positive relationship (though nonsignificant) between the body mass index and grip strength in the younger population (20s and 30s) and older group (70s), and this became an inverse relationship in the other groups. The overall conclusion was that BMI is non-significant to the normative values of grip strength. The authors discussed undernourished could have a greater impact and further studies were needed (Massy-Westropp et al., 2011). Limitations did include fewer participants in the lower BMI categories and a large number under age 40.

Though different positions of patients has been utilized, the American Society for Surgery of the Hand and the American Society of hand therapists have standardized positioning, instruction and calculation of grip strength (Massy-Westropp et al., 2011). This technique is for the patient to be seated, elbow by their side, and flexed to a 90-degree angle with wrist in neutral position. The grip dynamometer is positioned in the handle position II with support underneath the dynamometer. Three trials are given and averaged as has been documented for reliability (Massy-Westropp et al., 2011). To improve standardization, Roberts et al. (2011) had the forearm supported during testing and utilized the highest for three trials for a score for each side.

As discussed, strength is correlated to physical function. Grip strength has been correlated to total body strength and decline in grip strength correlate to a decline in physical function. This measurement is a quick screen of overall function and thus correlate to strength, which is a factor of fall risk. The cut off as per Bohannon (2015), which separates the male (26kg) and female (16kg), will be utilized to compare to the FFRT in this study.

Summary of Tools Related To This Study

After reviewing the literature, for this study the Timed Up and Go, Grip strength, fall history questionnaire, and the Activities-Specific Balance Confidence Scale were chosen for correlation with the unilateral and bilateral FFRT to determine which method of the FFRT would be most useful as a screening tool. These tools are easy to perform, requiring minimal equipment, space and time. They each contribute to fall risk identification and will not bias the FFRT by any similarity in tasks.

Forward Functional Reach

Forward reaching is a task that is often encountered while performing majority of the activities of daily living tasks (ADLs) by an older adult living independently (Row & Cavanagh, 2007). Reaching for pots on a stove, into a cabinet, getting a book or clothes from a shelf and the other components of ADLs require maintenance of good dynamic postural control to prevent falls (Jenkins, 2010). The FFRT is a test that has been developed for assessment of dynamic balance in the anterior-posterior movement plane (Duncan et al., 1990; Duncan et al., 1992). Due to the ease of administration based on time and equipment, this tool meets the requirement of a screening tool (Muir et al., 2010a). However, with the substitutions allowed by the unilateral reach; this tool may not identify the impairment that is needed for further assessment (Muir et al., 2010b).

In the initial study, Duncan et al. (1990) assessed the anterior posterior weight shift of 217 male veteran's age 70-104 yrs. by determining the maximum distance an individual could reach with one arm forward beyond the arm's length while maintaining a fixed base of support (BOS) in standing. This unilateral reach identified recurrent fallers at mean 6.44" (SD 5.3) and non-recurrent fallers mean 9.97" (SD 4.3) (Duncan et al., 1990). This has a range overlap of recurrent fallers 1.1-11.74" and non-recurrent fallers range of 5.67-14.27" which has confusion regarding what is a fall risk or non-fall risk. For those with single fall, the mean was 7.8 (SD 4.7) and non-fallers 10.2" (SD 4.3) (Duncan et al., 1990) resulting in overlapping range of fallers 3.1-12.5" and non-fallers range 5.9-14.5" again questioning what is identified as fall risk.

Brooks and Naglie (2006) studied the FFRT in relation to the Modified Barthal Index (MBI) in an inpatient geriatric rehabilitation center. The MBI is an index of function of ten daily activities that include various transfers, bathing, walking levels surfaces and stairs, dressing, toileting and grooming tasks. The correlation between FFRT and MBI was significant at admission and discharge indicating the relationship between reaching ability and daily activities (Brooks & Naglie, 2006). Therefore, if someone has a lower FFR, the ability to perform safely the reaching activities for daily tasks may be impacted and lead to falls or other injury.

People who fall have been shown to exhibit a greater amplitude in the medial/lateral direction with less consistent movement in the anterior/posterior movement (Brooks & Naglie, 2006). Since the FFRT, as per Duncan et al. (1990), allowed for movement strategies, *measurement* of FFRT should consider not only maintaining equilibrium but also the efficiency of *movement strategies* utilized (Goldman et al., 2014).

Wernick-Robinson et al. (1999) attempted to determine if FFRT was assessing dynamic postural control and if there was a difference between those with known balance deficits and the healthy elderly population. Using a camera system and force plates, the participants were recorded reaching forward. The results showed there was no difference between mean forward reach distance of those with balance deficits and those classified as healthy (Wernick-Robinson et al., 1999). They also found no difference between the mean of their study and the mean of the healthy matched individuals found by Duncan, mean=11.91" (30.25 cm) (Duncan et al., 1990; Wernick-Robinson et al., 1999). In the Wernick-Robinson study, the range, however, was significantly large for 3.68" (9.35cm) to 18.44" (46.85cm) (Wernick-Robinson et al., 1999). The researchers also found that compensatory strategies were both dynamic and static, concluding that compensatory strategy variability accounted for the similarity between the reach distances between their two cohorts and the Duncan study (Wernick-Robinson et al., 1999). Interesting that Wernick-Robinson et al. (1990) did find a moderate correlation between height and FFRT ($p<0.05$, $r=0.63$). This brings into question if actual distance of FFRT can predict fall risk or if height should be included in calculation of fall risk.

Reaching has been thought to be related to how far the subject can move the center of mass (COM) over the base of support, but laboratory measurements have had difficulty demonstrating this possibly due to the compensatory methods utilized by participants especially the scapula/shoulder complex (Mancini & Horak, 2010). The vertical projection through the COM is defined as the Center of Gravity (COG). Control of the COM in relation to the BOS, is really control of the COG (Shumway Cook & Woollacott, 2017 p. 154). The manner an individual coordinates body segments to produce the COG position may indicate underlying pathologies/impairments associated with the task constraints (Clark et al., 2005). Clark et al. (2005) examined the difference in COG during FFRT and limits of stability (LOS) testing using motion capture research and NeuroCom® balance master system. For both the FFRT and LOS test, the testing was done on the force platform but for the FFRT, the visual feedback was eliminated. Postural limits during the FFRT and LOS performance were assessed using the maximum COG excursion value. The results showed that during both the FFRT and LOS testing the participants adopted a variety of strategies, but that the maximum COG exertion was at least half a standard deviation higher for the LOS than for the FFRT (Clark et al., 2005). Clark et al. (2005) concluded that FFRT and LOS measure different aspects of reaching and leaning.

Jonsson et al. (2003) also used body kinematics and showed a low correlation (r=0.38) between reach distance and COP displacement. However, they did demonstrate a higher correlation (r=0.68) between reach distance and trunk rotation (Jonsson et al., 2003). This leads to the discussion that when one leans as per the LOS test, there is a different movement of the trunk than when one reaches as with the FFRT. Therefore, the FFRT may not be testing LOS as proposed by Duncan et al. (1990).

There have been studies suggesting the FFRT is not a sensitive instrument for identifying every person at risk. Reaching less than 25.4 cm as a criterion for fall risk may be a cut off for those at high risk and should be referred for further evaluation, but may not identify those at moderate risk (Behrman, Light, Flynn, & Thigpen, 2002). The FFRT has been used as a clinical measure of balance and a marker of physical frailty (Weiner et al., 1992) and as part of the Berg Balance Scale (Berg 1989a; Berg et al., 1989b; Jonsson, 2002). However, this criterion of <10” has been shown to not be sensitive to identify individuals with Parkinson disease at risk for falls (Behrman et al., 2002), Multiple Sclerosis (Frzovic, Morris, & Vowels, 2000), or other conditions. When identifying sensitivity and specificity of a testing tool, having both high sensitivity and high specificity would be the ideal situation, but determining whether sensitivity or specificity is most important for a given population can be challenging. Having a high specificity (where one is ruling more people in as being at risk) during a large screening event would include even those at low risk for referrals for further assessment. On the other hand, a high sensitivity (where one is ruling more people out as not being at risk) could eliminate those at risk from having further assessment. With the functional reach having the large range of >9.97” ± 4.3” (5.67-14.27”) as criterion for non-fallers and >10.2”±4.3” (5.9-14.5”) for single fallers (Duncan et al., 1990), already a population that could be eliminated from further assessment if 10” is used as the cutoff. There is also significant overlap in this classification; violating the isolation rule of an individual classified as only a faller or non-faller. Along with that, adding height as a factor of reach could also produce false positives and negatives. Those who are taller may reach further distance anteriorly based on their longer body size and excluded from the study long before they reach the criterion as fallers. The opposite could be true for those of shorter height who could not reach as far early years and included prior than their true weight shift ability indicates as fall risk.

While Duncan et al. (1990) allowed the trunk rotation and utilized the one arm reach, the BBS requires the participant to reach with both arms, when possible, to reduce the trunk rotation for more consistency across populations (Berg, 1989). Kage et al. (2009) compared 1-arm and 2-arm reach for the functional reach test to investigate the effect of trunk rotation on the reach distance in order to determine which test better reflects the center of pressure excursion. The authors utilized a motion analysis system with a force plate platform with 41 total participants: 26 women and 15 men with the average age 71.8 yrs. Each participant reached one arm and two arm with the distance recorded, amount of trunk rotation and movement of the center of pressure. Their results indicated that the center of pressure movement was significantly greater in the 1-arm reach and COP affected the reach distance greater than the trunk rotation (Kage et al., 2009).

Cavanaugh et al. (1999) showed that the elderly are less likely to shift their COP to the limits of their stability; especially in the sagittal plane. The FFRT measures the limits of stability in this sagittal plane and this impact on the center of pressure may be the underlying issue related to compensations with the unilateral reach.

Kinematic Studies of Functional Reach

The relationship in the COP and unilateral or bilateral reach is a component needed further review to help determine the background for this study. The large overlap range with the Forward Functional Reach by Duncan et al. (1990), allowed for compensations by the participants. The review of literature related to kinematic studies was done to determine the impact on the COP and functional reach based on the technique to reach forward.

Kage et al. (2009) investigated the difference between one arm and two-arm reach to determine the effect of trunk rotation in relation to the two movements and COP. By using a motion analysis laboratory on 41 participants with average age of 71, they did find that the one arm reach had a significant ($p<0.05$) higher excursion of the COP than the two-arm reach (Kage et al., 2009). However, this study only compared the difference in the excursion of the COP and the ultimate distance between the two methods of reach. There was no comparison to the variation of movement, height, nor relationship to fall risk prediction.

deWaroquier-Leroy et al. (2014) utilized force plates in a motion analysis lab to compare older participants with younger participants regarding the COP excursion and compensatory methods while performing the FFRT. They hypothesized that the different movement patterns may influence the FFRT and be age dependent (deWaroquier-Leroy et al., 2014). The authors utilized 29 volunteers (18 <50 yrs., 11 >75 yrs.) and excluded participants who had fallen two or more times in the previous 12 months or who could not stand for 30 seconds or move the shoulder to 90 degrees of flexion. The motion analysis system recorded, FFR distance, movement of C7, pelvic movement as identified by the markers on the ASIS and sacrum, the metacarpophalangeal joint of the right index finger. The results indicated the FFR distance was lower in the over 75-age group. The compensatory movements includes variation of pelvis moving forward in some, backward in some and alternating in some. Greater trunk rotation was noted in over 75 group. The consistency seemed to show that those who did not move the COP anterior, with/without compensatory methods, had shorter FFR distance (deWaroquier-Leroy et al., 2014).

Jonsson et al. (2002) utilized a whole body kinematic system, ground reaction forces and muscle activity (EMG) study on patients performing the FFRT to assess the center of pressure displacement and muscle activity to assess compensatory factors impact on the FFRT The FFRT had been suggested as a measure of displacement of center of pressure, which requires anticipatory muscle activity in the anterior tibialis. Jonsson et al. (2002) investigated what other factors besides COP displacement affects the FFRT therefore making FFRT more than just a functional balance test. The results illustrated that only 15% of the FFRT was related to center of pressure and the other 85% were impacted by trunk rotation, ankle motion and muscle activity (Jonsson et al., 2002). These variations in compensatory movements of trunk, ankle and muscle activity brings into question the variability of one arm reach in identifying fall risk.

These kinematic studies indicate that when using the unilateral reach, there are variations of how the COP moves with most movement occurring with trunk rotation. Those who are older tend to need to compensate more than the younger populations and when movement is controlled with bilateral reach, the distance forward is reduced. This suggests that bilateral reach may be more consistent across populations in predicting fall risk.

Preliminary/Pilot Studies Involving the FFRT

Two studies were done based on the literature review related to Forward Functional Reach. The first was a pilot study on younger adults to determine the influence of height on distance reach. The second was a preliminary study to compare the unilateral reach with bilateral reach regarding movement required for each to determine is the bilateral reach was more controlled than unilateral. Both were approved by the Institutional Review Board at the Alabama State University, where the study took place.

Reach To Height Of Young Adults: A Pilot Study. A pilot study was done with the primary purpose to explore the influence of height on the performance of FFRT amongst different gender, ethnic, and height groups on a group of young adult participants (Heitzman, et al., 2014). While a study by Lin et al. (2011) has shown that scores of the forward FFRT of older adults tend to be lower than those of younger people, the purpose of this pilot study was to see if any relationship between FFR distance and height existed before a full study was implemented on older adults. This would also give a baseline to determine changes with aging and ultimate fall risk.

A sample of convenience was used to recruit 40 healthy young adults participants (age 22-34) from the Alabama State University College of Health Sciences. The Institutional Review Board at the Alabama State University where the study took place approved the experimental protocol. All of the participants gave their informed consent prior to participation.

The exclusion criterion for participation was as follows: pain or limited shoulder range of motion affecting the performance of task, experience of an unexpected fall within the past month, inability to comprehend the test, and inability to perform the forward FRT without an assistive device. The participants were asked to fill out a questionnaire to determine which participants would be excluded from the study. 39 participants remained following the exclusion procedure, 20 African American (8 male and 12 female) and 19 Caucasian (7 male and 11 female).

The participants' height and weight was measured without shoes, using a measuring tape and weight scale, respectively. Following these measurements, all participants received a demonstration and the same verbal instructions on how to perform the forward FFRT. The original research study by Duncan et al. (1990) was utilized to implement the FFRT. The yardstick was secured horizontally on the wall by the use of Velcro at the level of subject's acromion process. A leveler was used for alignment of the yardstick on the wall to ensure this was parallel to the ground. The participants were then asked to stand barefoot with their feet shoulder width apart. The subject assumed a standing position with their dominant arm close to the wall, where the yardstick was secured. After taking the standing position, the participant was asked to flex their dominant shoulder to 90-degrees and extend the elbow, while making a fist with the hand. The initial starting point of the third metacarpal bone was marked on the yardstick. Then the subject was instructed to reach as far forward as possible while maintaining a fixed base of support and keeping the arm parallel to the ground at all times. As per the original study by Duncan et al. (1990), no attempts were made to vary how the participants reached as long as they did not fall, take a step or touch the wall. A researcher was always present to guard the subject in case of an episode of loss of balance. The reaching distance was configured by subtracting the starting point of the third metacarpal bone of the dominant hand from the end point. The participants were given two practice trials then three recorded trials, which were averaged for a final score.

The mean reach distance was divided by their height to determine the distance reached to height ratio. All participants were divided into one of three groups: short (<65 inches, n=14), medium (65-69 inches, n=12), and tall (>69 inches, n=13). The results had some variation within height groups but overall the taller an individual the further they can reach, average reach distance ranging from 13.91" for the short group to 17.08" in the tall group; a 3.17" difference. A Pearson's correlation coefficient was utilized to compare between the groups A two-tailed statistical correlation analysis test was used with alpha level set at 0.05 with the resulting *p* value= 0.0005 for the distance reached. This indicates a significant difference between the three height groups concerning the distance reached.

Each individual reach distance was also compared to their height to determine their percentage of their height that they could reach forward. When analyzing this distance reached to height ratio, an increase was noted with height from an average of 22.01% ratio in the short group to a 23.88% in the tall group; a 1.88% difference. The *p* value for this comparison showed no significant difference in distance reach to height ratio (*p*=0.154). The overall average of distance reached to height ratio was 23.17% (average range 22.01-23.88%). Gender variations were also found to be in this average range with females reaching at 22.85% and males at 23.78% of their height. Ethnicity also was analyzed with African American reaching at 22.43% of their height.

The hypothesis was confirmed that those that are taller do reach further than those that are shorter and is significantly different. However, the distance reached to height ratio is not significantly different between height groups nor ethnicity. This study was only focused on a small group (n=39) of healthy young adults age 22-34 and with no history of medical conditions that affect fall risk. Based on physiological changes with aging, the distance to height ratio may be different with older adults and would need further study to determine the normal changes versus changes with fall risk.

Kinematic Of Height and Unilateral/Bilateral Reach: A Preliminary Study. A second study, a preliminary study, was done to evaluate the compensatory strategies utilized between one and two arm forward reach between 3 different height groups of females over the age of 55. A second component of this preliminary study was to compare a younger and older female of similar height regarding the strategies utilized with one and two arm forward reach. Kage et al. (2009) evaluated the COP excursion between one and two arm reach but did not compare the differences between height and age. deWarquier-Leroy et al. (2014) assessed the compensatory strategies between younger and older populations and found greater trunk rotation in the older population but again did not compare differences between heights.

A sample of convenience was used to recruit four healthy participants from the Alabama State University College of Health Sciences. Three (3) females over the age of 55 were selected based on height so that one would be in the short (<5'4"), one medium (5'4"-5"9"), and one in tall (>5"9") groups measured as per the CDC Anthropometric Principles. (CDC, 2007) The fourth subject was a young adult under age 30 and recruited to fit into one of the height groups; this participant fit into the medium height group. Females only were utilized to control for variability that could occur between genders. Three of the four participants were African American with the Caucasian participant being the older participant in the medium height group that was compared to the young adult. All participants were screened to be able to stand without assistive device, raise their dominant arm to 90 degrees of shoulder flexion and have not fallen more than 2 times in the past month nor surgeries in the past 6 months that would impact their ability to participate in the study. The Institutional Review Board at the Alabama State University, where the study took place, approved the experimental protocol. All of the participants gave their informed consent prior to participation.

Kinematic data was captured using an 8 camera, infrared motion capture system (Vicon Motion Capture System, Vicon Motion Systems Ltd, Oxford, UK) at 100 Hz. Using double sided tape, nine reflective markers were placed C7, dominant hand of 2nd metacarpal phalangeal joint (MCP), sternal angle, and bilaterally on both acromion, anterior superior iliac spine and posterior superior iliac spine (Vicon, n.d.) The participants were asked to raise their dominant arm to 90 degrees and reach as far as possible forward without taking a step or losing their balance. After two practice trials, three trials were recorded. They were then asked to raise both arms to 90 degrees and repeat the reaching forward trials; two practice and three recorded. The average of the three-recorded trials was recorded.

A comparison of the three older adults between unilateral and bilateral reach distance was analyzed with the average measured (mm) at the point of greatest excursion of COM over COP for each reflective point. With comparing the three older adults with unilateral reach, the C7 and the sternum moved 300 mm further with the tallest participant (1300mm) as compared to the shortest participant (1000mm). The rotation of the shoulder was greater in the shorter participant (140mm) by 40mm than the tallest (100mm). Pelvic rotation was higher in both the medium and tall group (ASIS differential movement 220 in medium, 193 in tall) than in the short participant who only had a differential of 6 mm.

Comparison of the bilateral reach between the three height groups of older adults showed less variation of movement. While the C7 and sternum still had a 300 mm difference, the rotational differences were almost identical; shoulder differential was 15mm for the short, 10 mm medium and 5 mm tall participant. The pelvic rotation differential between right and left was even closer with short 9 mm, medium 5 mm and tall 4 mm. The scores are based on the starting position being at zero (0). There is greater variation with the unilateral reach regarding the rotation than with the bilateral reach with the shorter individual using less rotation in unilateral than the other heights but almost no rotation with bilateral reach across heights. This suggest various movement patterns exist between height groups that could be impacting reach distance when allowed to reach using preferred single arm reach as per Duncan study in 1990. This also suggests that with reaching forward with both arms, the participants utilize similar movement patterns versus when reaching forward with only one arm.

A comparison of the younger adult with the older adult of the same height (medium height) with one age 24 years, one age 60 years was also done. With unilateral reach, the older adult tended to move greater forward with the head and neck (1400mm vs 1200mm) and the younger moved more with the trunk via the sternum moving 1200mm vs 800mm in the older. Rotational differential was greater in the older participant by shoulder moving 180 vs 30 mm and pelvic rotation 220 mm vs 20mm. The bilateral reach in comparison, showed virtually no difference in movement patterns. Both C7 and Sternum moved forward; 1400mm in young and 1450mm in older for C7 and 1390 mm young and 1350 mm older for sternum. Rotation differential was minimal in both participants; shoulder 5mm young, 10mm older and pelvic 3 mm young, 5 mm older.

The older adult had greater rotation with unilateral than the younger adult similar to what deWarquier-Leroy et al. (2014) reported. This suggests the older adult had to rely on movement rotation to obtain reach distance. However, with the bilateral reach there is virtually no difference in movement between the young and the older participant of the same height. This study supported the hypothesis that using a bilateral arm reach reduces the variability of compensatory patterns between individuals with reaching forward.

These two studies demonstrate two conditions that impact the Forward Functional Reach Test. The pilot study demonstrated that while the raw score of unilateral reach is significantly different between the three height groups the distance reached to height ratio is not significantly different. The variation in height may be a reason there is such a large range when using the criterion for fall risk established for the Forward Functional Reach Test. This study became the basis for the methodology used for the current investigation and basis for the hypothesis that reach to height ratio (RHR) is more predictive of fall risk than reach distance. The preliminary study demonstrates that while the unilateral reach has greater variability between height groups of older adults and between the young and older adult in the same group, the bilateral reach was significantly closer in movement. This suggests that the bilateral reach may be more consistent among all height groups when assessing the Forward Functional Reach. This preliminary study became the basis for the hypothesis for this current study that the BFFR may be more predictive of fall risk. The combination of both these studies is the basis for the hypothesis in this study that the BRHR is more predictive for fall risk

Summary

Falls are a major health concern; financially and emotionally, as one ages. There are many intrinsic and extrinsic indicators for increased potential for falls and identifying those risk factors that can be modified is an important preventative need. While many tools are available for assessing impairments involved in fall risk, some are not feasible (time, equipment, space) for screenings to identify those in need of full assessments. The FFRT has been used both as an assessment of movement in the sagittal plane as needed for daily tasks but has an overlapping range that may misclassify an individual as fall risk. The preliminary studies related to unilateral and bilateral reach and related to raw score versus distance to height ratio indicates that some improvement may be possible to have this tool more predictive of future falls. This study will look at the differences between one and two arm reach to determine if controlling the movement variations of the one arm reach can be more reflective of fall risk. The raw score has shown a large range and does not take into account an individual height. Therefore, using a reach to height ratio will be studied to determine if this reduces the variations between height groups versus using the raw distance score. The participants will be identified as fall risk by screens of ABC, TUG, Grip Strength, and fall history/health identifiers. These were chosen to ensure that the areas of history (comorbidities, fall history, diagnosis identified as fall risk), self-reported fear of falling, a dynamic balance task and a strength task are utilized as these components have been identified as factors related to falls. These tools were chosen due to the ease of performance as well as the variation of tasks done in standing and sit should reduce fatigue factor. Each of these tasks measures a single dimension of fall risk and do not duplicate each other. By identifying the participant's composite fall risk score with these measures, the FFR test methods under study can be compared to the composite score for determining if the current FFR test method can be improved to predict fall risk.

CHAPTER III. Methods

Introduction

This chapter will focus on the research methods used in this study. Falls are a major issue in the aging adult population. The purpose of this study was to determine the effect of height and reach methods on the ability of the FFRT to accurately identify fall risk. A secondary purpose was to determine if a bilateral reach to height ratio (BRHR) could more accurately identify fall risk by: 1) reducing the variability of substitutions that can occur with unilateral reach, and 2) reduce the risk of false negatives/positives due to height. A more accurate assessment of fall risk would allow interventions based on individual characteristics versus generic reach numbers. The research design, study procedures including rationale for the choice of participants, statistical analysis, and resources will be presented in this chapter.

Research Design

This investigation was a cross sectional cohort study sample of aging adults of over age 60, who were of various heights across 3 height groups and ethnicities living in the Montgomery, AL area. The fall risk is high within older adults. A pilot study had been completed evaluating the distance to height ratio on younger adults between ages of 18-35 with an average age of 25 $\pm$ 2.53 (Heitzman et al., 2014). The focus of this study was on older adults over the age of 55. Each participant was assessed in their individual performance on the standard UFFR and the BFFR in relation to three different outcome measures that were used to identify physical decline and fall risk and the individual health/fall history. The Reach to Height ratio for each of the methods was compared as well as the raw distance reached to determine if there is a significant difference between each height group for each method. These four methods of the FFRT were compared to how the individual participant performed on four outcome measures that indicate fall risk; 2 performance methods Timed Up & GO (TUG) and handgrip strength, one self-reported measure Activities Based Confidence Scale (ABC), and the individual’s health/fall history. These 4 outcome measures were used to develop a FRCS.

Using a sample stratification, each participant was assigned one of three cohorts based on their height: short (<5’5”), medium (5’5”to 5’9”), or tall (>5’9”). This enabled a between height group comparison of the data obtained for both the raw distance and reach/height ratio for both the UFFR and BFFR. This older cohort was also be stratified by age groups, 60-69, 70-79 and >80 years to compare changes between age groups for identification of changes that may occur with increased age.

Study Procedures

Participants

Following approval from the Alabama State University and Nova Southeastern University (NSU) Institutional Review Boards (Appendix A), the study took place at the Crump Senior Center in Montgomery, Alabama during 5 sessions between March 16 and May 12, 2018. This Center is an activity center that has a wide variety of programs for community dwelling individuals which include, health screens, exercise class, educational programs and more. A transportation program allows those who no longer drive to come to the center. This Center was chosen due to the large number of community dwelling individuals that would enable a large percentage of older adults who would be considered non-fall risk to determine true variations between height groups versus the multitude of covariance that could assist with individuals in an assistive living facility. This would also allow early identification of fall risk factors that may be more prevalent in those still living in their own home. The Crump Senior Center Executive Director agreed to allow data to be collected at the center and a letter of agreement was obtained (See Appendix B).

To determine the sample size for this correlation study, the online calculator from Statistical Decision Tree (n.d) was utilized. Using the conventional 0.800 for power and 0.05 for alpha the following sample sizes: r=.4, n=47; r=.5, n=29; r=.6, n=20 were obtained. (Statistical Decision Tree, n.d.) This study utilized a snowball recruitment method to recruit 75 participants with the goal of 25 for each of the three height groups.

Recruitment began with flyers posted in the Center with dates the study would take place. The recruitment process included speaking at several exercise and education sessions held at the Crump Center on Mondays and Fridays during January and February 2018. Permission was received from the Executive Director for short presentations to take place at the conclusion of the regularly scheduled exercise classes that include: yoga, tai chi, chair exercise classes, as well as during the health screening events. During these presentations, the purpose of the study was explained and questions answered (See Appendix C). Eligibility requirements were reviewed and the potential participants were instructed that they would be asked to perform a few tasks in order to ensure eligibility prior to participating in the full study. They were assured of ability to withdraw at any time and if they chose to withdraw this would not influence their relationship with the Crump Center nor with Alabama State University. The confidentiality of the results were presented to them at this time as well. This information was reviewed with each individual again the day of the study and a signed consent form to participate in the study obtained from each potential participant prior to any testing (See Appendix D). Explanation was given that even though they signed the consent, once testing starts, they may be found to be ineligible for continuing in the study. They may also withdraw at any time with no negative consequences in relation to the Senior Center and to Alabama State University or any of the respective representatives of both institutions. Signup sheets (APPENDIX E) were left at the front desk with instructions for the participants to come to the Center on the day they selected, and to wear closed toe flat shoes and comfortable clothing, as they would be doing various walking, standing and sitting tasks.

Eligibility was based on the participants meeting the inclusion/exclusion criteria listed in Table 3.1. Since this study focused on older adults, the age of 60 has been identified by the CDC as a marker of older age (CDC, 2015b). The Berg Balance Scale is a commonly used full assessment of balance (Lusardi, 2017). According to the Berg Balance Scale (BBS), a non-faller should be able to stand for two minutes with eyes open and feet shoulder width apart (Berg, 1989a; Berg et al., 1989b). Performance of the FFRT, the individual must be able to stand for a short period of time without holding onto the assistive device or any other assistance. To ensure the participants were able to do the FFRT, this study utilized the Berg Balance Scale criteria for standing time. The TUG requires the participants to independently (with or without assistive device) walk 10’, turn and walk back for a total of 20’ (Podsiadlo & Richardson, 1991). The FFRT requires the participants to raise their arm to 90 degrees of shoulder flexion to perform the test (Duncan et al, 1990). As a result of the required physical activity during testing, the participant would need to be able to tolerate physical activity and vital signs are the most effective measure to determine if the individual would be at risk in performing physical activity (Frese et al., 2011). According to the most recent guidelines by the American College of Physicians (Qaseem, Wilt, Rich, Humphrey, Frost, & Forciea, 2017), the target for resting systolic blood pressure (SBP) is to be below150mmHg for older adults following initiation of medication intervention and anyone with SBP >200 mmHg should be evaluated by the physician prior to initiating any physical activity. Any resting BP >160mmHg for SBP should be referred to physician and any SBP > 200mmHg, any diastolic BP > 110 or <90, or heart rate >120bpm is a red flag for physical activity (Frese, et al, 2011). Based on this criteria, for safety of the individual, any SBP >200 or heart rate >120bpm were excluded from the study.

Table 3.1: Inclusion/Exclusion Criteria

Inclusion	Exclusion
●60 years of age or older ●Ability to stand for two minutes unsupported without balance loss ●Ability to raise and maintain arms parallel to the ground ●Ability to walk 20 feet independently with/without assistive device	●Cognitive deficit ●Recent UE surgery or diagnosis that limits ability to grip or raise UE to 90 degrees of shoulder flexion without pain ●Any other surgery or diagnosis that prevents their ability to walk 20' or lean forward during the FFRT such as LE or back/abdominal surgery ● Vital signs that preclude participation in physical activity (BP>200/>110 or diastolic <90, HR >120bpm)

Data Collection

When the participants first arrived, the purpose was explained and they were instructed that they would be assessed for inclusion criteria as part of the study. If they were unable to continue based on the criteria of the first four tasks, they would not be included. The participants were able to review the consent form along with having the form read to them and any questions answered prior to signing. They signed the form prior to beginning any of the stations/tasks. At this time, a clipboard with the data collection form (see Appendix F) was given to them to take to each station. The data form had an identification (ID) number that matched the consent form number. All consent forms were kept separate from data forms from this point onward to ensure confidentiality of participants.

Following signed consent forms, data was collected during one session with each participant. This included, in the following order: height, vital signs, ability to stand unsupported for two minutes, and a demographic/medical fall history. This enabled the researcher to identify inclusion and exclusion criteria prior to preceding the next tasks. Once the participants were identified as eligible, each performed the following tasks by randomly rotating through the stations as availability occurs:

completion of the self-reported Activities Based Confidence Scale, Timed up and Go test, Handgrip strength testing, and FFRT. During the FFRT, the individual's performed the UFFR first followed by the BFFR.   Total testing time for any individual took no longer than 45 minutes. Physical therapy graduate students assisted in all data collection; except the Forward Reach tests, which was done by the primary researcher. These students had been trained in all testing procedures. Each student had been assessed by the primary researcher by performing the testing on each other as well as other graduate students to ensure reliability of performance. Each student administered one test during which a script was utilized to ensure consistency and intra rater reliability (See Appendix G-L for full scripts with each task).

Part One: Inclusionary/Exclusionary Criteria. The participants had the first four criteria performed to determine eligibility to continue. If any of these criteria were not met, the participant was excused from the study and did not continue with Part 2. Their file was taken to the final collection point for all forms, which was designated by the researcher, for safekeeping. A graduate student was stationed at this point to maintain security of all forms.

Height. Height was measured first to determine if the individual was of a height required for the stratification of 25 in each height group. This was done using a freestanding stadiometer to ensure consistency (See Appendix G). The participant stood on the base barefoot facing outward and the height will be measured. According to the National Health and Nutrition Exam Survey (CDC, 2007), the participant was asked to stand with the body weight evenly distributed, both feet on the platform and instructed to stand with heels together and toes pointed outward to approximately 60 degrees angle with the back of head, shoulder blades, buttocks, and heels making contact with the backboard (CDC, 2007). For those who were older and had curvature of the spine or those who were overweight who could make the 4 point contact, they were asked to stand as erect as possible (CDC, 2007).

In order to determine the height groupings to ensure that 25 participants were stratified into each three height groups, the groupings were based on the CDC Health Survey of Height and Weight (CDC, 1973). This identifies the height range for people through their growth years to the maximum height that occurs in early adulthood around age 18/19 years. This health survey also demonstrates that more females are in the shorter height range and males in the higher height ranges at the end of the growth years (CDC, 1973).

The Baltimore Longitudinal Study on Aging (National Institute Of Health (NIH), n.d.) found that despite common perceptions, aging adults lose only 2" of height (females) and 1" of height (males) by age 70 and only 1" more by age 80 years. Most of these losses are due to physical inactivity and/or nutrition along with other medical conditions based on such things as medications and comorbidities. Therefore, for this study on FFRT, the height at maximum growth chart will be utilized. Based on this, the cut 50% mark is used, which puts 50% of female in the short category and 50% of the males in the tall category.

Table 3.2: Height at Maximum Growth (NIH, n.d.)

Percentage of age group	Males cm (inches-feet)	Females cm (inches-feet)
5%	165.7 (65.236", approx...5'5)	152.3 (60.03", approx.... 5')
10%	167.3 (65.88", approx.. 5'5")	154.6 (60.866", approx.... 5')
25%	171.3 (67.44", approx.. 5'7")	158.6 (62.44", approx.... 5'2")
50%	175.8 (69.21", approx.... 5'9")	162.5 (63.97", approx.... 5'3")
75%	180.4 (71.023", approx.... 5'11")	167.6 (65.984", approx.... 5'5")
90%	185.3 (72.95", approx.... 6')	171.4 (67.48", approx.... 5'7")
95%	186.4 (73.385", approx.... 6'1")	175.3 (69.0", approx.... 5'9")

*color identifies the groupings for this study

The participants in this study were classified in the height group short (<5'5"), medium (5'5"-5'9"), or tall (>5'9"). Once 25 participants for any height group is obtained, no further participants for that grouping were included.

Demographics/Medical History. With the help of a research assistant, the participants completed a medical history/demographic form (see Appendix H), that will had their identification (ID) number inserted into the form, to identify any medical issues that would impact fall risk and history of falls over the last two months; both would be utilized in analysis for fall risk identification during data analysis. For the purpose of this study the definition of a fall by Noohu et al. (2014) was utilized where a fall is when a person comes to a lower surface or on the ground unintentionally. A fall according the American Geriatrics Society current guidelines on fall prevention (AGS & BGS, 2011), three questions should be asked of all older adults: 1. Have they fallen two or more times in the past 12 months? 2. Have they recently fallen? 3. Do they have concerns regarding their balance of walking? Answering yes to any of these three questions place them in the risk for falling category. If the answers were "no" then other factors may place them into risk for falling based on history of falls (injury or not), medications, gait/balance, strength, heart rate, dizziness, neurological conditions, and external issues of footwear/environment or use of assistive device (AGS & BGS, 2011). The medical history form will reflect these issues to identify if the participant was placed in the fall risk group or non-fall risk group for correlation to the FFRT during analysis. The exclusion criteria included any recent neurological or orthopedic diagnosis, injury, surgery that would prevent the individual form performing the physical tasks of TUG, Grip Strength, or FFRT.

Vital Signs. Vital signs of Blood Pressure (BP), heart rate (HR), and respiration rate (RR) were be taken before beginning the physical activity portion of the study to determine eligibility and at conclusion of participation in the study to ensure the individual was safe to leave the building. The technique outlined by Frese, Fick, and Sadowsky (2011) was be used with the participant sitting in a comfortable chair and arm resting on the table to their side for five minutes prior to taking vital signs. The back and feet were supported on the floor with the participant sitting with legs uncrossed. The participant was instructed not to talk during the testing of vital signs. After the five minutes of rest, a research assistant palpating the radial pulse and counting beats for one full minute took the HR. The respiration was also taken while the researcher's hand was still on the pulse but watching the chest movement for one full minute. These values were recorded. The patient was asked to expose the upper arm by moving any clothing up the arm or removing outer layers. A blood pressure cuff of each small, standard and large size was available for use as indicated by the participant's body size. Arm circumference were measured using tape measure and if 22-26 cm small cuff will be used, 27-34 cm standard cuff size and if >35 cm a large cuff was used (Frese et al., 2011). The blood pressure cuff was applied 1" above the antecubital crease and with the bladder over the brachial artery. This allowed the bell of stethoscope to be placed over the strongest area of the brachial pulse without pushing up on the cuff. With the forearm resting on the table, the research assistant palpated the radial pulse and slowly inflated the cuff until the pulse was not palpable. The reading on the cuff was noted, and the cuff deflated. After a one-minute wait period, the research assistant placed the stethoscope over the brachial artery, supported the participant's arm so that they were relaxed and the arm was at the level of the heart. The cuff was slowly inflated to 20 mmHg higher than the point when the radial pulse was no longer palpable. The cuff was deflated at a rate of 2 mmHg every second. The point where the ausculatory pulsations was heard was recorded as the systolic BP and where these pulsations disappear was recorded as diastolic BP. This was repeated after a minute rest and the average of the readings recorded (Frese et al., 2011). Both arms were measured and the higher of the two noted. Failure to follow this technique could result in false readings. If the arm is higher than the right atrium of the heart there will be a lower BP reading and if below the heart there will be a higher reading (Frese et al., 2011). Red flags from the vital signs that prohibited the participant from continuing in the study included: resting HR > 120 bpm, resting systolic BP> 200 mmHg or < 90 mmHg, resting diastolic BP

>110mmHg, or any patient complaints of angina pain or dizziness. A patient who had a resting systolic BP of > 160 mmHg and had no diagnosis that is being managed by their primary care provider was encouraged to see their provider (Frese et al., 2011, Qaseem et al., 2017). The vital signs measurement were done at the conclusion of the research testing to enable the participant to safely leave the building; return to baseline measurements within 10 minutes of concluding the study (Frese et al., 2011).

Standing Unsupported. To be able to perform the FFRT, the participant must be able to stand unsupported. As stated, eligibility was based on the participants being able to stand independently without use of an assistive device for two minutes to participate. Any individual who required assistance (an assistive device or person-assist) to maintain a static standing posture was excluded from the study. The participant was asked to stand with their feet shoulder width apart and arms at their side keeping eyes open for 2 minutes as described in the BBS (Berg, 1989). A gait belt was placed around the participant prior to beginning timing and a chair was available directly behind them (not touching their legs) in case the participant needed to sit down. The research assistant stood close enough to assist if needed during the timing. If a patient used an assistive device, they were asked to let go of the device when the researcher says, “go” and that is when the timing started. Timing stopped if patient lost balance by having to take a step, reach for their assistive device, sit down or the research assistant had to grab the patient to keep them from falling. Time was recorded at time of stoppage or at two minutes whichever occurred first. Any individual unable to stand unsupported for the two minutes was excluded from the study.

Part Two: Balance Measures and Functional Reach Measures. Once the participant successfully completed the four preliminary stations, they were included in the entire study. They proceeded to the next four in any order based on availability of performing the tasks with limited wait time. The random order ensured that no fatigue due to the multiple testing will be affecting the overall testing results and no test could influence previous or post testing.

Activities-Specific Balance Confidence Scale. The self-reported Activities-specific Balance Confidence Scale (ABCs) was performed with each participant to assess their perceived risk of falling during daily tasks (Appendix I). The ABC was chosen as this self-reported test is utilized with community dwellers making this more appropriate for the participants in this study. This was printed in handout format with their ID number (Appendix I) and read to each individual by a research assistant. The following instructions were read as per Powell and Myers (1995):

> "For each of the following, please indicate your level of confidence in doing the activity without losing your balance or becoming unsteady from choosing one of the percentage points on the scale form 0% to 100%. If you do not currently do the activity in question, try and imagine how confident you would be if you had to do the activity. If you normally use a walking aid to do the activity or hold onto someone, rate your confidence as it you were using these supports".

Each participant was questioned regarding one's understanding of these instructions and probing occurred as needed for any specific question regarding their understanding of the activity. Upon completion of all 16 items, the research assistant calculated the confidence level by dividing the total percentage by 16. Any score < 67% was considered risk for falls (Lajorie & Gallagher, 2004).

Hand Grip Strength. The AGS guidelines (AGS & BGS, 2011) discuss strength as an indicator of functional decline. The handgrip strength was utilized to assess strength as an indicator of functional decline based on Bohannon (2008), mobility decline based on Yorke et al. (2015), and early identification of decline by Goldman et al. (2014). This allowed a strength measure in a seating position to reduce the fatigue factor of participants in repeated standing task activities. The procedure for performing this task was based on the technique described by Roberts and Denison (2011), which is based on the standardize positioning by the American Society for Surgery of the Hand and the American Society of Hand Therapists (See Appendix J). The participant was seated with feet flat on the floor and arm at their side with elbow flexed to 90 degrees and forearm in the neutral position. The forearm and handgrip dynamometer was supported. The dynamometer was placed in the handle 2 position. Three trials were given to each arm with one-minute wait between trials by alternating arms. The highest of the three trials for each side was utilized. Participants were classified as fall risk if they could not obtain the grip strength of 16 kg for females or 26 kg for males (Bohannon, 2015).

Timed Up And Go. The Timed up and Go (TUG) was utilized as a measure of functional mobility that includes strength of LE in getting out of the chair, gait and balance while walking, turning and returning to sit (Appendix K). According to the protocol by Podsiadlo and Richardson (1991), TUG was performed. A chair with arms was placed against the wall for stability with a measurement of three meters from the front leg of the chair marked on the floor. There were no other markings or obstacles that may have distracted the participant. A gait belt was placed around the participant for safety. A research assistant walked behind the participant for safety and by being behind them did not impact the speed of walking. The participant was asked to rise from the chair, “walk at a safe and comfortable pace” to the three-meter mark turn around and return to the chair and sit down (Podsiadlo & Richardson, 1991). Timing began when the researcher said, “go” and ended when the participant was seated back in the chair. The participant was allowed to use the assistive device if needed and this was be marked on the data collection form. There was one practice trial to ensure understanding of instructions, then one recorded timed trial. The breakdown for the time for TUG was 9.05s for 60-64.9 yrs., 9.77 s for 65-8=69.9 years, 9.96 s for 70-74.9 years, and 10.86 s for those 75 and older (Wang et al., 2016).

Forward Functional Reach. The Forward Functional Reach tests were done by the primary researcher in two steps (Appendix L). The first was unilateral (the method used by Duncan et al. in 1990 and 1992), and the second was the bilateral reach. This was done in this order so that the more controlled bilateral reach would not affect how the person reaches unilateral. Large 2.5’ by 2’ grid paper on easel pad was secured to the wall with the lines aligned with a leveler to ensure the parallel lines were parallel to the ground. A line was taped onto the floor for the participants to stand with their toes just behind the line. The participants were asked to stand barefoot behind the line with feet shoulder width apart with their dominant arm next to the wall. A gait belt was applied to the participants for safety and a chair behind them if needed in case of loss of balance. The researcher was standing by at all times to assist in case of loss of balance. The participant’s acromion next to the wall was marked on the grid paper for subsequent trial alignments. Each participant was asked to raise their dominant arm until the shoulder is at 90 degrees and make a fist with their hand. The initial starting point of the third metacarpal bone was marked on the grid paper. The participant was instructed to “reach as far forward with the one arm as possible while keeping their feet on the ground, not taking any step, touching the wall, falling and to keep the arm parallel to the ground at all times.” As per the original study by Duncan et al. (1990), no attempts were made regarding how the participants reached as long as they did not fall, take a step, or touch the wall. The ending point of the third metacarpal was marked on the grid paper. Each participant was given two practice trials then three measured recorded trials, which were then averaged. The reaching distance was determined by measuring the distance between the starting point of the third metacarpal bone of the dominant hand and the end point of the same bony landmark. After a five-minute rest break, the participants repeated this test only this time they reached with both arms at 90 degrees, keeping both arms parallel to the floor and moving at the same distance. Each participant ultimately reached forward ten times, two practice and three recorded trials for each unilateral and bilateral reach.

Resources Used For Study

This study took place at the Crump Senior Center in Montgomery, Alabama. Flyers were made at Alabama State University to post at the Center along with sign-up sheets for times during the presentations done to recruit participants. At the center, a room was allocated for health fairs and education sessions, which was large enough to accommodate this study. Four tables were used for initial contact with signing of the consent form, the completion of the demographic/medical history form, and for use during vital signs and handgrip strength. Twenty-four chairs without wheels and at least 2 with armrests for the TUG were obtained. Two chairs were placed each table and each station for the ABC, TUG, Grip and FFRT stations; one for the participant being tested and one for waiting. Extra chairs were placed at the entrance of the room as needed due to waiting by participants. These chairs were provided by the Crump Center for usage. Twenty-four clipboards were used for the consent forms, data documentation at each station, ABC forms and demographic/medical history forms. These were obtained from Alabama State University. For testing, all forms were copied at Alabama State University; 80 of each and brought to the Center. Handgrip dynamometer, blood pressure and the stadiometer were borrowed from the PT Program at Alabama State University with verification of recent calibration. The primary researcher bought grid paper as an easel pad of 30 sheets and blue 2-inch wide painters tape. The tape was used for marking the 3 meter path on the floor for the TUG test and securing the grid paper to the wall for the FFRT as well as marking a line on the floor for the participants to stand behind during FFRT. Eight Graduate students were recruited to assist with the data collection at the Center. Water was provided for all participants and research assistants. The data analysis was done using the personal computer system of the primary researcher.

Data Analysis

Data analysis was done using the Microsoft Excel version 2013 with the features of the Analysis ToolPak. The performance of each participant on the 4 fall risk outcome measures identified by the AGS (2011) as measures to be done annually on aging adults was identified as being fall risk (1) or non-fall risk (0) based on normative cut score values for each measure. The Fall Risk Composite Score (FRCS) was developed based on these 4 outcome dichotomy scores; which were added together for an overall FRCS ranging from 0 (no fall risk on any measure) to 4 (fall risk on all four measures). During analysis, anyone with a FRCS of 1 or higher was considered fall risk as the AGS reports that anyone having *any* fall risk should be referred for full assessment (AGS 2011).

Descriptive Statistics was done to identify the demographics of the participants that included ethnicity, height group by age group, and number of participants identified as fall risk by the 4 fall risk measures for each height and age group. The average of each reach method was determined for each height group. Using an ANOVA, which is used to determine the difference between the means for 3 or more groups, between height group analyses was done to determine if there was a statistical difference between the three height groups with regards to each of the 4 reach methodology; raw distance UFFR and BFFR, and reach to height ration unilaterally and bilaterally. This analysis was done for the entire population as well as for non-fall risk participants based on the FRCS. Performing an analysis specifically for those as non-fall risk assists in eliminating the variations that may occur based on limitations of balance control in those identified as fall risk by other measures. A multi-correlation analysis was then performed to examine the strength of relationship of height and the FRCS with each of the 4 reach methods; UFFR, BFFR, URHR, BRHR.

The UFFR, which is based on the procedure utilized by Duncan et al. (1990), at the cut score of 10" as identifying fall risk was analyzed in relation to the FRCS. Participants were identified as false positive if the FRCS was zero (0) but the UFFR was 10” or less. Those participants identified as false negative had a FRCS of 1 or greater with a UFFR of greater than 10”. Each height group was then analyzed regarding the number of participants as false negative and false positive based on this relationship between UFFR and the FRCS.

A multilinear regression was then done to examine the strength of the effect of each of the 4 reach methods had to the FRCS. A scatterplot of developed for the UFFR and the BFFR based on the results of the regression. These scatterplots were used to help identify if changes in the normative cut scores based height could improve the identification of those at fall risk based on the FRCS.

CHAPTER IV. Results and Analysis

During initial sign up, seventy-two participants signed up for the study. Of these 72, the short and medium height groups filled quickly but there were minimal participants in the tall height group. As a result, the researchers went through the Crump Center to recruit taller individuals. A total of 84 (72 from the original recruitment and 12 more during individual recruitment) people consented to participate.

Of the 84 participants who agreed to participate in the study, a total of 66 qualified to continue in the study based on pre-screening inclusion/exclusion criteria. Two were unable to stand for the required two minutes without an assistive device, three had resting blood pressure readings outside the safe parameters, two who had signed up for the study did not show, and 11 who came on later dates in the study were at the height group where 25 participants were already obtained. Each participant was classified as fall risk (1) or no fall risk (0) for each of the tasks as listed in Table 4.1 based on the cut scores as identified by the specific study. The Fall Risk Composite Score (FRCS) was then determined by the total number for each individual based on these scores; range from 0-4 depending on the individual participant.

Table 4.1 Tasks and Fall Risk Classification

Research activity/task	Fall risk cut point criteria identified by the study	Study utilized for the cut point criteria
Health History (HHx)	If any of the following are Yes, they are classified as a fall risk: • 2 or more falls in past 12 months, • fall in the past 2 months, • self-concerns regarding balance/gait, • medications for neurological or cardiac conditions, • use of assistive device	AGS, 2010
Activities specific balance confidence scale (ABC)	< 67% is identified as fall risk	Lajorie &Gallagher, 2004
Hand grip strength (GRIP)	< 16kg (female), 26 kg (male) is identified as fall risk	Bohannon, 2015

Timed up and Go (TUG)	> 9.05 sec for age 60 > 9.77 sec for age 65 > 9.96 sec for age 70 >10.8 sec for age ≥75	Wang, 2016

Participant Demographics

The final 66 participants enrolled in the study included 25 in the short height group, 25 in the medium height group, and 16 in the tall height group. There were a total of fifty-two (79%) females and fourteen (21%) males. Nineteen (29%) were African American, and the rest registered as Caucasian. Thirty-six (55%) were between the ages of 60-69, twenty-three (35%) between 70-79 and seven (10%) were age 80 or older as shown in Figure 4.1. Table 4.2 represents the overall breakdown of participants by demographics.

Figure 4.1. Participants by Height and Age Groups

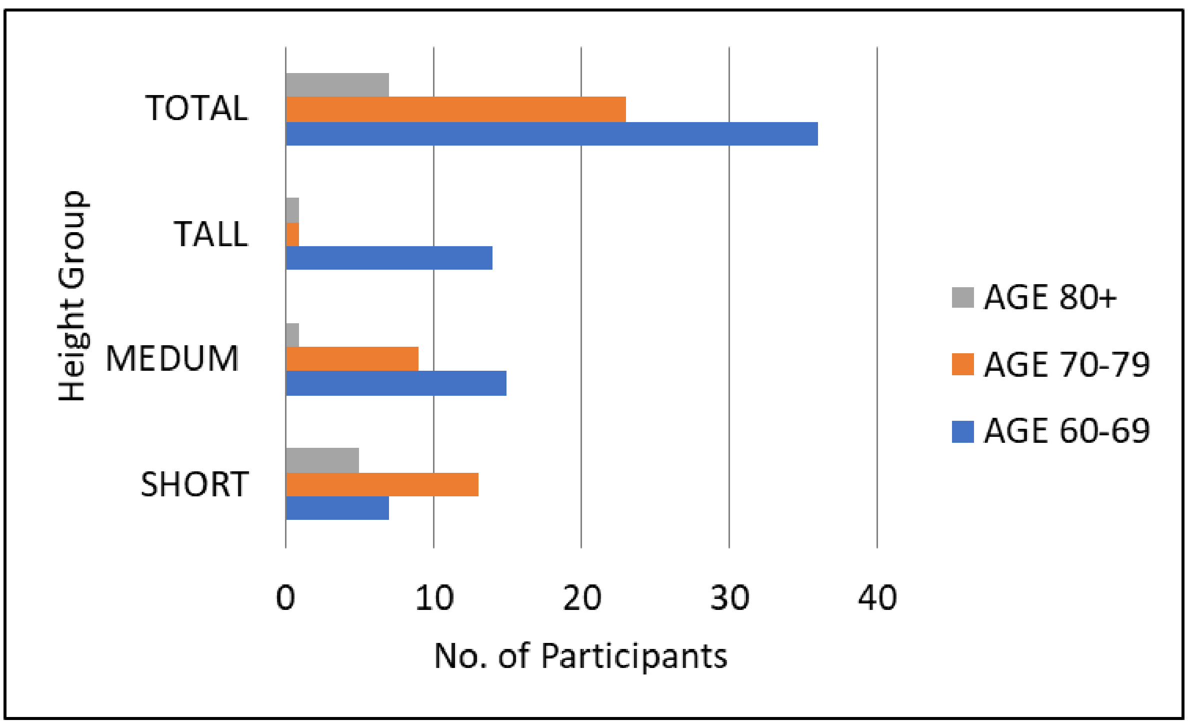


Table 4.2 Participants Demographics by Height Group

Height Group	Male	Female	Age 60-69	Age 70-79	Age >80	African American	Caucasian
<5’5”	1	24	7	13	5	8	17
5’5”-5’9”	2	23	15	9	1	9	16
>5’9”	12	4	14	1	1	2	14

Fifteen (23%) reported not doing any exercise outside of daily activities, twenty-one (32%) reported participating in structured exercises 1-2 times per week, nineteen (29%) reported exercising 3-4x/week, and eleven (17%) reported exercising greater than 5 days/week. Seven (11%) of the participants utilized an assistive device for at least 25% of the day (which was noted by the researchers during the interview process to be when outside the home). Twenty-three (35%) had a health history that was defined as a fall risk: dizziness, Diabetes neuropathy, past stroke or other brain injury, or reported falling in the past 90 days. A total of 26 (39%) total participants were identified as fall risk by the AGS (2010) guidelines. Table 4.3 represents the breakdown of the number of participants identified as fall risk by the cut point value for each fall risk measure. Twenty-six (39%) of the total participants were in one or more predicted fall risk categories. Only six (23% of the total fall risk participants) were determined to be a fall risk in only one category (health history), and four of those six were in the tall height participant group. The other twenty (77% of fall risk participants/30% of the entire population) were classified in one or more categories of fall risk.

Table 4.3 Number of Participants Identified by the Fall Risk Measures Data per Height Group

Height Group	HHx	ABC	TUG	GRIP
<5’5”	9	7	10	6
5’5”-5’9”	6	5	5	1
>5’9”	8	2	3	3
Total population (66)	23 (35%)	14 (21%)	18 (27%)	10 (15%)

Fall Risk Composite Score

As stated, each participant's FRCS of 0-4 was the sum of each individual fall risk measure; History, ABC, TUG and Grip strength based on the individual cut point value for each measure; 0 for non-fall risk, 1 for fall risk. For the analysis, any individual with a FRCS of zero (0) was considered non-fall risk and any score 1 or greater was considered a fall-risk. This FRCS was utilized throughout the data analysis to compare the fall risk to the non-fall risk participants concerning the four reach methods in this study. In the short height category, 10 individuals (15%) had a FRCS ranking of 1 or greater; identifying them as a fall risk in at least one category. In both the medium and tall height groups, eight participants were classified as a fall risk; 32% and 50% respectively. Overall, 26 participants out of the 66 total were classified as a fall risk by at least one of the four fall risk measures (FRCS of 1 or greater); 39% of the entire population. Table 4.4 shows the number of participants for the fall risk and non-fall risk categories in each height group and the average FRCS in each height group for those at fall risk.

TABLE 4.4 Number of Participants Identified as non-fall risk and fall risk by height/Average Fall risk composite score for those at fall risk

Fall risk/non-fall risk	Short	Medium	Tall	Total
# Non-fall risk	15	17	8	40
# Fall risk	10	8	8	26
Average FRCS for those with scores 1 or greater	3.3	2.1	2	2.5

In order to compare differences with forward reaching as one ages, participants were stratified by age within each height group of fall risk and non-fall risk. Table 4.5 shows this comparison of a FRCS that identifies them as fall risk and non-fall risk and based on age within each height group. This breakdown has more participants classified as non-fall risk by the FRCS in the younger aging adult group than the older age groups. There was less participants in the tall group in the older two age groups. This inequity across the 3 age groups based on this study's participants limited this study to further analysis by height groups using the entire population of 66 participants.

Table 4.5 Number of Participants as Fall Risk and Non-Fall Risk based on FRCS by Age and Height Group

Height Group	Short		Medium		Tall		Total	
Age Group	Fall	Non-fall	Fall	Non-fall	Fall	Non-fall	Fall	Non-fall
60-69	1	6	2	13	6	8	9	27
70-79	6	7	6	3	1	0	13	10
>80	3	2	0	1	1	0	4	3

The criteria of reaching forward less than 10-inches (Duncan et al., 1992) was used to identify participants as fall risk and non-fall risk using the UFFR. Using this criteria for UFFR, 22 participants were identified as being at fall risk; 18 in short height group, three in each medium and tall groups. Forty-four (44) were identified as non-fall risk: seven in short height group, 22 in medium, and 15 in tall height groups.

The FRCS was compared to the UFFR to determine the ability of the UFFR to identify fall risk in comparison to other balance measures. Since the AGS guidelines (2011) classify anyone with one fall risk to be referred for full assessment of fall risk and identifies the 4 measures used in this study as measures for annual review of fall risk, the FRCS of one (1) or greater is classified as fall risk and meets the AGS criteria. Of the 22 participants identified as fall risk by the UFFR, 10 participants, all in the short height group, had a FRCS equal 0.0, meaning they were not identified as fall risk by any of the 4 fall risk measures classified by the AGS as fall risk measure, yet the UFFR identified them as fall risk. Conversely, 14 of the 44 UFFR non-fall risk predictions had a FRCS greater than 0.0, indicating the UFFR did not identify them as fall risk when other measures did. Those included two in the short, five in the medium, and seven in the tall height group. Tables 4.6 and 4.7 identify the breakdown of the UFFR versus the FRCS and percentage correct by the UFFR. Overall, the UFFR was correct 52% for the short height, 80% for the medium height and 56% correct for the tall height group, and 64% for all groups combined based on the FRCS scores; indicating disagreement between the UFFR and other AGS recommended fall risk measures.

TABLE 4.6 Number of Fall Risk Participants by UFFR Compared to FRCS

UFFR and FRCS	Short	Medium	Tall
UFFR fall risk with FRCS > 0	8	3	1
UFFR fall risk with FRCS = 0	10	0	0
Correct %	44.44	100	100

Table 4.7 Number of non-Fall Risk Participants by UFFR Compared to FRCS

UFFR and FRCS	Short	Medium	Tall
UFFR non-fall risk with FRCS = 0	5	17	8
UFFR non-fall risk with FRCS > 0	2	5	7
Correct %	71.43	77.27	53.33

Unilateral Reach

Unilateral Forward Functional Reach Distance

Height group. The average reach distance for all participants by height group is shown in Table 4.8 as well as the average distance reached for those identified by the FRCS as being at fall risk and non-fall risk.

Table 4.8 Average Unilateral Functional Reach (UFFR) Distance in Inches by Height Group

Height Group	Participants with FRCS > 0 (range)	Participants with FRCS=0 (range)	All participants (range: SD)
Tall	11.1 (6.2-15.8)	16.0 (14.0-17.8)	14.5 (6.2-17.8: 3.0)
Medium	8.2 (7.4-16.1)	13.3 (10.5-17.2)	12.5 (7.4-17.2: 2.4)
Short	7.8 (4.0-12.5)	10.5 (7.1-15.6)	9.4 (4.0-15.6: 3.0)
Overall Average	9.1 (4.0-16.1)	13.3 (7.1-17.8)	12.2 (4.0-17.8: 3.4)

Between height group comparison. An analysis using the ANOVA was done to determine if there was a significant variance between the three height groups regarding the UFFR. With all participants included in the ANOVA, a statistically significant difference between the groups (p=5.7x10^{-}

[6]) was found as shown in Table 4.9. To eliminate the variability of reach that could occur based on fall risk, an analysis for only those considered non-fall risk based on the FRCS was done. With only the non-fall risk participants included in the ANOVA, statistically significant difference between the groups ($p=3.0x10^{-6}$) was still found as shown in Table 4.10.

Table 4.9 ANOVA of UFFR for All Participants between Height Groups

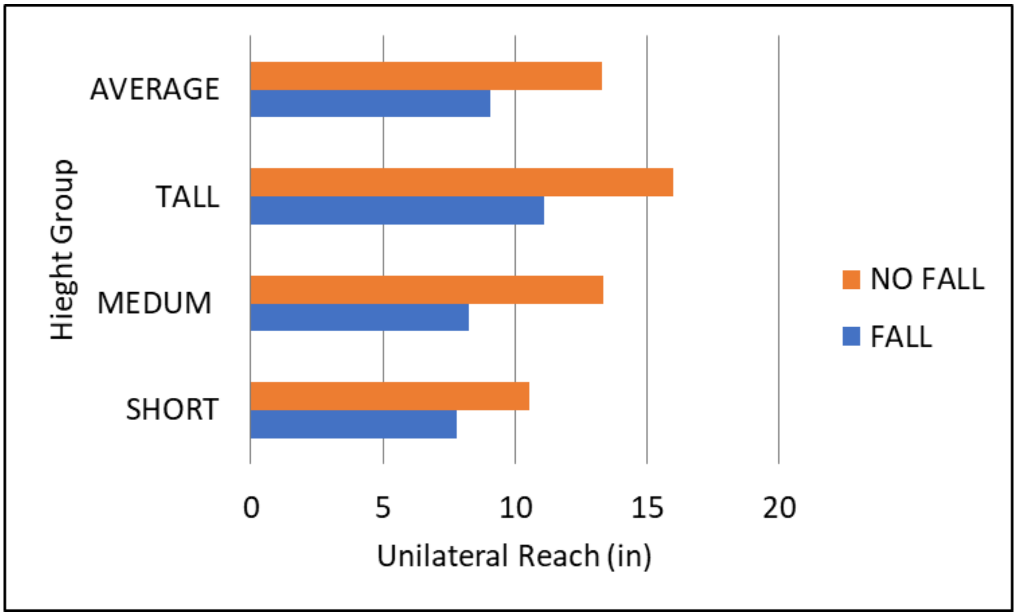
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	241.70	2	120.85	14.87	$5.7x10^{-6}$	3.15
Within Groups	487.59	60	8.12			
Total	729.29	62				

Table 4.10 ANOVA of UFFR for Non-fall Risk Participants between Height Groups

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	163.13	2	81.57	18.27	$3.0x10^{-6}$	3.25
Within Groups	165.19	37	4.46			
Total	328.32	39				

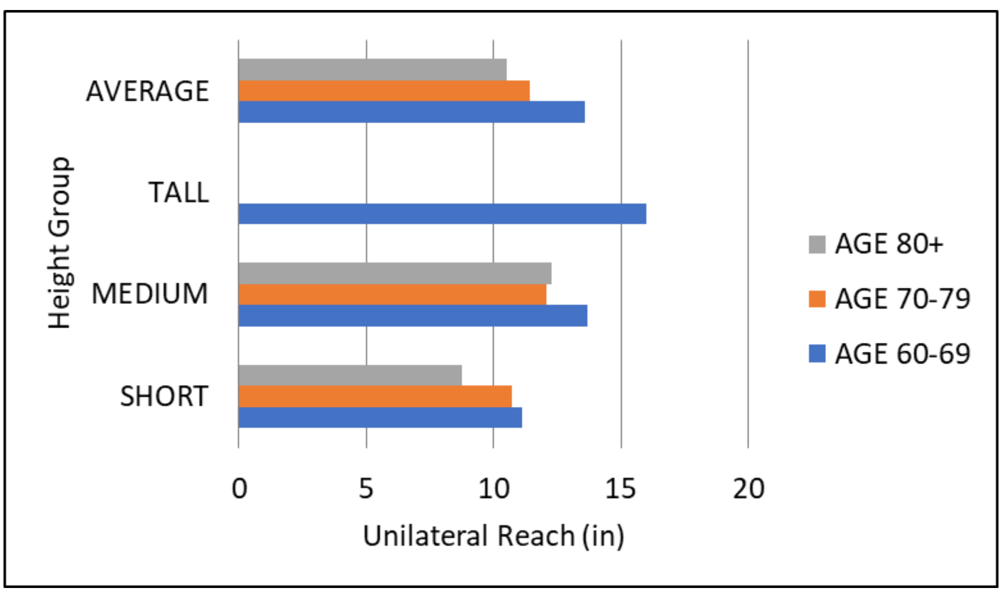
A visual representation of this comparison of those at fall risk and non-fall risk by height is shown in Figure 4.2. The figure clearly demonstrates whether one is identified as fall risk or non-fall risk by other measures, participants reach distance increases as height increases.

Figure 4.2 UFFR Scores by Height Group and FRCS Fall Classification



Age Group. The comparison of age groups for non-fall risk as per the FRCS does demonstrate that overall, as one ages, reaching forward does decrease as shown in Figure 4.3. Again, there is variation between height groups with the overall data average of forward reach; with reach distance increasing with height.

Figure 4.3: UFFR Non- Fall Risk Population Group by Age and Height Group



Unilateral Reach To Height Ratio

Each participant's unilateral reach distance was divided by his or her height in inches to determine the URHR. This value was then utilized to analyze the differences between height groups.

Height Group. Based on the individual height groups, the reach to height ratio increased for all participants; from 15.3% to 20.3% (short to tall) and for the non-fall risk participants from 17.0% to 22.4% (short to tall) as shown in Table 4.11.

TABLE 4.11 Average Unilateral Reach to Height Ratio % by Height Group

Height Group	Participants with FRCS > 0 (range)	Participants with FRCS=0 (range)	All participants (range: SD)
Tall	18.2 (8.8-24.7)	22.4 (20.1-25.4)	20.3 (8.8-25.4: 4.3)
Medium	16.4 (11.3-24.3)	20.0 (16.0-25.2)	18.9 (11.3-25.2: 3.6)
Short	12.7 (6.5-19.6)	17.0 (11.9-25.2)	15.3 (6.5-25.2: 4.8)
Average	15.8 (6.5-24.7)	19.8 (11.9-25.4)	18.4 (6.5-25.4: 2.9)

Using an ANOVA, the significance between height groups for the non-fall risk participants for the URHR was found to be statistically significant ($p=0.0012$) as shown in Table 4.12. However, this statistical difference is smaller than the UFFR ($p=3.0x10^{-6}$) shown in Table 4.10.

Table 4.12 ANOVA Unilateral Reach to Height Ratio for Non-fall Risk Participants between Height Groups

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	167.33	2	83.66	8.08	0.0012	3.25
Within Groups	383.15	37	10.35			
Total	550.48	39				

Bilateral Reach

Bilateral Forward Functional Reach Distance

Height Group. The average BFFR varied from 8.2” in the short group to 12.3” in the tall group, a difference of 4.1” for all participants, and a difference of 2.4” for the non-fall risk group. This is shown in Table 4.13.

Table 4.13 Average Bilateral Forward Functional Reach in Inches by Height Group

Height Group	Participants with FRCS > 0 (range)	Participants with FRCS=0 (range)	All participants (range: SD)
Tall	8.9 (5.3-16.2)	13.8 (12.0-15.0)	12.3 (5.3-16.2: 3.1)
Medium	9.0 (6.5-13)	11.5 (8.8-13.7)	10.7 (6.5-13.7: 2.6)
Short	6.9 (3.7-11.2)	9.0 (6.3-19.6)	8.2 (3.7-13.3: 2.6)
Average	8.3 (3.7-16.2)	11.4 (6.3-19.6)	10.4 (3.7-16.2: 2.9)

Similar to the UFFR, the distance reached with the BFFR increased as height increases and statistically significant difference between the groups ($p=7.8x10^{-7}$) was found for the non-fall risk participants based on the FRCS as shown in Table 4.14.

Table 4.14 ANOVA of Bilateral Reach for Non-fall Risk Participants between Height Groups

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	125.42	2	62.71	21.06	$7.8x10^{-7}$	3.25
Within Groups	110.17	37	2.98			
Total	235.59	39				

Bilateral Reach To Height Ratio

Height Group. The comparison between height groups for the BFFR to height ratio was also done. Based on the bilateral reach to height ratio (BRHR) for all participants, this ratio increased from

13.2% to 17.0% (short to tall) and the non-fall risk participants increased from 14.2% to 19.4% (short to tall); shown in Table 4.15.

Table 4.15 Bilateral Reach to Height Ratio % by Height Group

Height Group	Participants with FRCS > 0 (range)	Participants with FRCS=0 (range)	All participants (range: SD)
Tall	14.9 (7.6-22.5)	19.4 (17.1-21.6)	17.0 (7.6-22.5: 4.3)
Medium	13.7 (8.1-19.6)	17.2 (13.5-20.7)	16.1 (8.1-20.7: 3.1)
Short	11.2 (5.7-17.4)	14.2 (12.0-20.8)	13.2 (5.7-20.8: 4.1)
Average	13.3 (5.7-22.5)	16.9 (12.0-21.6)	15.4 (5.7-22.5: 4.0)

Using an ANOVA for comparison between height groups for the non-risk participants, a statistically significant difference was found (p=0.00052), shown in Table 4.16. However, this statistical difference is smaller than the BFFR ($p=7.8x10^{-7}$) shown in Table 4.14.

TABLE 4.16 ANOVA Bilateral Reach to Height Ratio for Non-fall Risk by Height Groups

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	130.41	2	65.21	9.34	0.00052	3.25
Within Groups	258.32	37	6.98			
Total	388.73	39				

Comparison of the Bilateral and Unilateral Reach

Correlation of Parameters

A Pearson Correlation matrix of all study parameters was done and shown in Table 4.17. The correlation between the four reach methods, the fall risk outcome measures, FRCS and height was analyzed to determine any correlation; positive/negative and strength of the relationship. This correlation analysis shows that there is a high correlation between unilateral and bilateral reach methods

(>0.91). Both unilateral and bilateral reach methods are moderately correlated with height: UFFR 0.63, BFFR 0.59, URHR 0.47 and BRHR 0.42. All four-reach methodologies were moderately negative correlated with the FRCS between -0.54 to -0.57 indicating that as the fall risk increased the reach capability decreased. The correlations of FRCS with the TUG (0.83), demographic history (0.83) and ABC (-0.72) are much higher than the correlation between the four reach parameters with fall risk composite score.

Table 4.17 Correlation Matrix

	Male / Female	Age	Height	demographic fall risk category	ABC score	Tug time	grip average Right	grip average Left	unilateral reach average	unilateral reach to height ratio	bilateral average	bilateral reach to height ratio	combined fall risk score
Male (1)/ Female (2)	1.00												
Age (yrs)	0.22	1.00											
Height (in)	-0.63	-0.44	1.00										
demographic fall risk category (0-1)	-0.09	0.25	0.05	1.00									
ABC score	-0.21	-0.33	0.25	-0.47	1.00								
Tug time	0.28	0.45	-0.33	0.53	-0.83	1.00							
grip average Right	-0.64	-0.38	0.58	-0.25	0.45	-0.57	1.00						
grip average Left	-0.62	-0.37	0.56	-0.23	0.41	-0.54	0.97	1.00					
unilateral reach average	-0.46	-0.60	0.63	-0.29	0.51	-0.64	0.63	0.59	1.00				
unilateralreach to height ratio	-0.35	-0.58	0.47	-0.35	0.52	-0.64	0.56	0.52	0.98	1.00			
bilateral average	-0.46	-0.58	0.59	-0.33	0.54	-0.64	0.62	0.57	0.95	0.94	1.00		
bilateral reach to height ratio	-0.34	-0.55	0.42	-0.39	0.55	-0.64	0.55	0.50	0.92	0.94	0.98	1.00	
combined fall risk score	0.08	0.45	-0.17	0.83	-0.72	0.83	-0.51	-0.48	-0.54	-0.57	-0.54	-0.57	1.00

Multilinear Regression

A multilinear regression was done using the entire sample population (Table 4.18) to determine the strength of all four reach components (input variables) in relation to the fall risk composite score (output variable) and computed a *p* value ranging from 0.62-0.79 with the bilateral reach methods having a slightly stronger influence on the FRCS than the unilateral reach methods. The sum of the squares (SS) shows that the regression of 47 for all four-reach methods accounts for 35% of the data variation (47/134). The population was divided by height group and the multilinear regression was repeated for all four-reach components to determine the significance of each reach component in a specific height group in relation to the FRCS (Tables 4.19-4.21). The reach components had stronger influence in the short group than the medium and tall groups based on the p-values, but the linear regression strength was better for the tall group (R^2=0.29 for short, =0.42 medium, and =0.60 for tall). The reach components have a greater impact on the output of the FRCS as one gets taller based on the SS: short 27%, medium 42%, and tall 57%.

Table 4.18 Multilinear Regression of Four-reach components to Fall Risk Composite Score: Full Study Sample

	Multiple R	R Square	Adjusted R Square	Standard Error	Obser-vations	
	0.59	0.35	0.31	1.19	66	
ANOVA	*Df*	*SS*	*MS*	*F*	*Signif. F*	
Regression	4	47.21	11.80	8.29	2.07×10^{-5}	
Residual	61	86.79	1.42			
Total	65	134				
	Coef.	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	4.568	0.658	6.943	2.90×10^{-9}	3.25	5.88
Unilateral reach average	-0.745	2.186	-0.341	0.734	-5.12	3.63
Unilateral reach to height ratio	0.379	1.455	0.260	0.795	-2.53	3.29
Bilateral average	1.158	2.607	0.444	0.659	-4.05	6.37
Bilateral reach to height ratio	-0.866	1.740	-0.498	0.620	-4.35	2.61

Table 4.19 Multilinear Regression of Four-reach components to Fall Risk Composite Score: Short Height Group

	Multiple R	R Square	Adjusted R Square	Standard Error	Obser-vations	
	0.54	0.29	0.14	1.57	25	
ANOVA	*Df*	*SS*	*MS*	*F*	*Signif. F*	
Regression	4	19.96	4.99	2.02	0.13	
Residual	20	49.48	2.47			
Total	24	69.44				
	Coef.	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	4.191	1.130	3.709	0.001	1.83	6.55
Unilateral reach average	-12.881	14.879	-0.866	0.397	-43.92	18.16
Unilateral reach to height ratio	7.827	9.257	0.846	0.408	-11.48	27.14
Bilateral average	15.189	17.704	0.858	0.401	-21.74	52.12
Bilateral reach to height ratio	-9.452	11.025	-0.857	0.401	-32.45	13.55

Table 4.20 Multilinear Regression of Four-reach components to Fall Risk Composite Score: Medium Height Group

	Multiple R	R Square	Adjusted R Square	Standard Error	Obser-vations	
	0.64	0.42	0.30	0.96	25	
ANOVA	*df*	*SS*	*MS*	*F*	*Signif. F*	
Regression	4	13.06	3.27	3.55	0.024	
Residual	20	18.38	0.92			
Total	24	31.44				
	Coef.	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	4.267	1.131	3.772	0.001	1.91	6.63
Unilateral reach average	-0.946	10.589	-0.089	0.930	-23.03	21.14
Unilateral reach to height ratio	0.669	7.044	0.0949	0.925	-14.02	15.36
Bilateral average	0.205	12.700	0.0161	0.987	-26.29	26.70
Bilateral reach to height ratio	-0.406	8.431	-0.048	0.962	-17.99	17.18

Table 4.21 Multilinear Regression of Four-reach components to Fall Risk Composite Score: Tall Height Group

	Multiple R	R Square	Adjusted R Square	Standard Error	Obser-vations	
	0.77	0.60	0.46	1.01		
ANOVA	*df*	*SS*	*MS*	*F*	*Signif. F*	
Regression	4	16.82	4.21	4.14	0.03	
Residual	11	11.18	1.02			
Total	15	28				
	Coef.	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	6.231	1.375	4.531	0.0008	3.20	9.26
Unilateral reach average	1.686	7.117	0.237	0.817	-13.98	17.35
Unilateral reach to height ratio	-1.526	5.138	-0.297	0.772	-12.84	9.78
Bilateral average	-2.313	8.935	-0.259	0.800	-21.98	17.35
Bilateral reach to height ratio	1.728	6.445	0.268	0.794	-12.46	15.91

Summary

A total of 66 participants participated in this study with 55% age 60-69, 35% age 70-79 and 10% over age 80. The demographics have 23% males/77% females and 29% African American/71% Caucasian. Thirty-nine percent (26 participants) were identified as fall risk by at least one of the fall risk measures (medical/fall history, TUG, Grip Strength and ABC) with an average FRCS of 2.5. Based on the FRCS, the UFFR based on Duncan et al. (1990) cut score was in agreement 64% as identifying fall risk with the greatest agreement occurring in the medium height group.

Using the between group analysis for the non-fall risk (FRCS=0) participants, all four reach methods had a statistical difference; UFFR p=5.7x10^{-6}, URHR p=0.0012, BFFR p=7.8x10^{-7}, BRHR p=0.0052. The Pearson's Correlation demonstrated a moderate correlation between the four reach methods and height; UFFR 0.63, BFFR 0.59, URHR 0.47, BRHR 0.42. This correlation also shows a negative correlation between the reach methods and the FRCS ranging from -0.54 to -0.57. The

Multilinear Regression shows that the reach methods have a greater impact on the output of the FRCS as one gets taller; Short group 27%, Medium group 42% and tall group 57%. This multilinear regression also shows that the bilateral reach methods had slightly greater impact on the FRCS than the unilateral reach methods.

CHAPTER V. Discussion

Analysis Discussion

Based on the calculations as discussed in Chapter 3, a sample size of 68 participants was determined to be required to achieve the moderate effect size (>0.80) for this correlation study. The study plan was to have 75 participants, but the final count was 66 after screening participants for exclusion criteria. Using the online calculator from Statistical Decision Tree (n.d), the power calculation for 66 participants for correlation between height to reach yielded a power of 0.9921 with correlation set at 0.5 and significance level at 0.05 (Statistical decision tree, n.d.). However, in order to achieve a confidence interval of 90%, the sample size calculation using a z-score has a different sample size requirement. Using a z-score equal to 1.645 with the SD of 0.5, the result is a sample size of 268.9 (approx. 270 participants) (Smith, 2018):

$$\text{Necessary Sample size} = ((\text{Z-score})^2 * (\text{StdDev} * (1-\text{StdDev}))/(\text{margin of error})^2$$

$$\text{Or} \quad ((1.645 \times 1.645) \times .5(1-.5))/ .05 \times .05 = 270$$

With the 66 participants, the z score=0.8124 which is a 79% confidence interval, resulting in a moderate effect size (Smith, 2018).

Age and Fall Risk

Wang et al. (2016) found that falls and fall risk increase as one ages. For this study, the percentage of those identified as fall risk in each age group increased with age. Table 4.5 and Graph 4.3 show the comparison of those identified as fall risk and non-fall risk by the FRCS. Since the FRCS was based on 4 outcome measures supported by AGS (2011) and that any one of these measures would indicate the fall risk, a FRCS of >0 indicates fall risk. The FRCS classified fall risk for 9 out of 36 participants (25%) age 60-69, 13 of 23 participants (56%) age 70-79, and 4 of 7 participants (57%) age 80 and older; thus showing an increase as one ages. This supports the prevalence data reported by the

CDC (2015) and the WHO (2007) discussed in Chapter 2 that has shown there is an increased prevalence of fall risk as an individual ages.

Lin and Liao (2011) reported that the older adult did not reach as far as the younger adults. Graph 4.3 demonstrates that in the older age groups for this study, as one ages, the average reach distance with UFFR did decrease. The overall average of UFFR distance for this study of older adults was found to be 13.3". Heitzman et al. (2014) found in the pilot study of younger adults discussed in Chapter 2, that the average UFFR distance of this younger population was 15.6". This is a 15% decrease in reach distance between older adults and younger adults; supporting Lin and Liao results that as one ages the distance reached decreases. Since the ability to reach forward has been associated with balance limitations resulting in increased fall risk (Hassankhani et al,. 2012; Muier et al., 2016) this decrease in FFRT seen progressively across all age groups supports the increased risk for falls as one ages which is noted in the literature (Kramarow et al., 2015; CDC 2015b; Wang et al., 2016; Larson et al., 2017; WHO 2018).

Is there a correlation between height and a FFRT distance?

Wernick- Robinson et al. (1999) found a moderate correlation between height and UFFR (p=0.05, r=0.63). The data shown in Table 4.8 and Figure 4.2 demonstrates that taller people can reach further whether they are classified as a non-fall risk or fall risk as identified by at least one recommended fall risk measure (FRCS >0). The correlation (Table 4.17) also shows a moderate correlation between height and reach (r=0.63). This supports the hypothesis that height does affect the ability to reach forward. In figure 4.3, the participants identified as non-fall risk with forward reach were shown by age groups and height. This comparison shows that height does impact the distance one reaches but also shows the decline in reaching ability across all height groups as one ages.

Using the current FFRT cut score of 10 inches as defined by Duncan et al, (1990), the data shown in Table 4.6 demonstrates that in this study, the UFFR identified ten people in the short height group as fall risk candidates when no other fall risk measure (as per the AGS Guidelines, 2011) identified the participant as a fall risk (FRCS=0). These ten participants are likely “false-positive” results based on the current FFRT cut point value of 10”. Whereas, in the medium and tall height groups, the UFFR classified 5 and 7 (respectively) as non-fall risk when at least one other fall risk measure identified the participant as fall risk. These 12 participants are likely “false-negative” results based on the current FFRT criteria. Overall, the UFFR only agreed with the other fall risk measures 64% of the time with the greatest disagreement in the short and tall height groups. This supports the theory that height is a component of the FFRT and is a factor in the number of false positive and false negative as identifying fall risk when compared with fall risk measures recommended by the AGS (2011). Therefore, Hypothesis 1: There is a correlation between height and the distance a person can reach using the FFRT, is accepted.

Is there a statistical significant difference in reach distance between three height groups when performing the FFRT?

As discussed in Chapters 1 and 2, there is disagreement in the literature regarding the ability of the FFRT identifying fall risk as well as what the cut point score is for identification of fall risk. Thomas and Lane (2005) found in their study that FFRT did not differentiate fallers from non-fallers (p=0.053). Lusardi et al. (2017) determined a posttest probability for predicting falls (which they identified as a fall within 6 months of testing). For a positive FFRT result, the posttest probability was 67 and for a negative FFRT, the posttest probability was 15. However, the cut value varied from < 5.9” to < 8.7” depending on the study. (Lusardi, et al., 2017). This variability of cut point value is shown in multiple studies. Duncan et al. (1990) found a mean FFR distance of 11.91”. With separating recurrent fallers from non-fallers, a difference was found. For those considered recurrent fallers, the mean was 6.44" (SD=5.3") and for non-fallers the mean was 9.977" (SD=4.3") (Duncan et al., 1990). This range based on the standard deviation shows a large overlap between fallers and non-fallers with regards to the FFR distance. In 1990, both Duncan et al. (1992) and Weiner et al. (1992) determined the mean to be 10.9" with a range of 4.3" to 16.5". Wernick-Robinson et al. (1990) found the same 11.91" but the range for their study was 3.68" to 18.44" with no difference between those with balance limitations and those who were considered healthy.

Since maintain the COG within the BOS is an important component of daily activity (Clark et al., 2005), this study used a between height group comparison to determine if the identification of fall risk is related to height. Using an ANOVA for the entire population, the UFFR was found to be statistically different between height groups; p=5.7x10^{-6}. In order to control for the variations that could result as a result of fall risk, the ANOVA was then performed on only those identified as non-fall risk (FRCS=0) for all 4 reach methods. A statistical difference between height groups was found for all 4 reach methods; UFFR p=3x10^{-6}, URHR p=0.0012, BFFR p=7.8 x 10^{-7}, BRHR p=0.00052. This supports the Hypothesis 2a: There is statistical difference between 3 height groups when using each of the unilateral FFR, bilateral FFR. Since a statistical difference was found between the URHR and BRHF this rejects the Hypothesis 2b: There is no statistical difference when using unilateral reach to height ratio and bilateral height to ratio.

Unilateral Reach Pilot Study Comparison. In chapter 2, the pilot study of the younger adults compared the UFFR distance and URHR between height groups was discussed (Heitzman, et al., 2014). Heitzman et al. (2014) studied non-fall risk in (based on inclusion/exclusion criteria for the study) young adults between ages of 20-35. The 3.2" difference was found in UFFR between short and tall height groups and the between groups analysis was found to be statistically significant (p value= 0.0005). In the older population of non-fall risk individuals based on the FRCS=0, a UFFR 5.5” difference was found between these two height groups and the between groups analysis was also found to be statistically different (p=3.0x10^{-6}). This also supports the Hypothesis 2a Therefore, the statistical difference between UFFR was found in both the younger and older populations indicating that one value cannot be utilized across height groups when identifying fall risk using the UFFR.

A comparison of the URHR data of the younger adult from this pilot study by Heitzman et al. (2014) to the non-fall risk data of the older adults in this study indicates the older adult URHR of 19.79% is a decrease of 3.16% from the younger group. This may indicate normal physiological aging results in reach to height ratio decline of approximately 3%. However, when comparing the URHR for the younger population by height groups, the 1.88% difference between height groups was statistically not significant (*p* value=0.154), allowing a use of one URHR across height groups to determine the normative value that younger adults should be able to reach 22% of their height(Heitzman et al., 2014). For the older age group in this study, the URHR had a 5.59% difference between height groups and was found to be statistically significant (p=0.00123). The URHR was similar in younger height groups but not in older height groups the use of URHR varies with age. This URHR statistical difference of older adults rejects Hypothesis 2b which indicates that no one RHR can be utilized across height groups.

Differences between the data presented in Chapter 2 for younger and the data presented in Chapter 4 of the older non-fall risk population are shown in Table 5.1 for ease of comparison.

TABLE 5.1 Comparison of Studies for Unilateral Forward Reach of Young vs Older Non Fall Risk Adults.

Age Group	Reach	Short	Medium	Tall	Group Ave	Difference between short & tall height groups	Significance (*p* value)
<35yrs	Reach (inches)-UFFR	13.9	15.8	17.1	15.6	3.2	0.0005

	Reach to height ratio (%)-URHR	22.01	23.76	23.88	22.9	1.87	0.154
>60yrs	Reach (inches)-UFFR	10.5	13.3	16.0	13.3	5.5	$3.0x10^{-6}$
	Reach to height ratio (%)-URHR	16.97	19.99	22.42	19.79	5.45	0.00123
Diff.	Reach (inches)-UFFR	3.4	2.5	1.1	2.3		
	Reach to height ratio (%)-URHR	5.04	3.77	1.46	3.11		

Preliminary Study Comparison. Several studies were presented in Chapter 2 that discussed the compensatory movements associated with the UFFR. Wernick-Robinson et al. (1999) found differences in the compensatory movements between those identified as fallers and those as non-fallers. In 2003, Jonnson et al. found a moderate correlation between reach distance and trunk rotation (r=0.68). Clark et al. (2005) utilized force plates and the NeuroCom® and found LOS and UFFR had a variety of strategies between participants. Kage et al. (2009) compared 1 and 2 arm reach and found that the COP displacement was greater with 1 arm reach than with 2 arm reach. deWarquier-Leroy et al. (20150 found greater trunk rotation in older adults than in younger adults.

The preliminary study on bilateral reach was focused on the movement variations between the younger and older adults when performing the unilateral versus bilateral reach. The movement variations reduced with bilateral reach both between ages and between height groups, suggesting bilateral reaching may be more consistent across age groups and heights. Therefore, this current study looked at both the BFFR and the BRHR across height groups for older adults. The ANOVA performed across the height groups indicated that both the BFFR and the BRHR were statistically significant between height groups (p=7.8x$10^{-7}$and 5.2x10^{-4} respectively). This further supports the Hypothesis 2a and reject Hypothesis 2b.

Overall, the 4 methods of reach, UFFR, URHR, BFFR and BRHR all had statistical differences between height groups. Hypothesis 2a: There is statistical difference between 3 height groups when using the UFFR and BFFR is accepted by this study and Hypothesis 2b: There is statistical difference between 3 height groups when using the URHR and the BRHR is rejected by this study.

What is the relationship between unilateral and bilateral arm reach when using the distance reached and the reach to height ratio in comparison to a fall risk composite score (FRCS) based on 4 other fall risk/decline to frailty tools?

A Pearson Correlation Analysis (Table 4.17) identifies a strong correlation (>0.90) between all four reach methods. With comparison to height, the 4 reach methods had a moderate correlation; with the reach distance being a stronger correlation than the reach to height ratio; UFFR 0.63, BFFR 0.59, URHR 0.47, BRHR 0.42. The reach methods had a negative moderate correlation to the FRCS with both reach to height ratio methods showing a slightly greater negative correlation at -0.57 than the reach distance methods of -0.54. All 4 reach methods had the strongest negative correlation with the TUG score; -0.64. Both these negative correlations indicate that as the FRCS increases and as the TUG time increases the reach ability decreases. The ABC score has a moderate positive correlation with the 4 methods with both bilateral methods showing a slightly higher correlation; UFFR 0.51, URHR 0.52, BFFR 0.54 and BRHR 0.55. The Grip strength also had a positive correlation with the reach distance methods being slightly more correlated than the ratio methods at 0.63 (UFFR) and 0.62 (BFFR) compared to 0.56 (URHR) and 0.55 (BRHR). As these positive correlations of ABC and Grip strength decrease the reach ability also decreases. The demographic information of medical history and fall history had the lowest correlation to the reach methods ranging from 0.29-0.39 with the bilateral methods slightly more correlated than the unilateral methods. Overall, the reach methods were moderately correlated with the fall risk measures and FRCS with the distance methods being slightly greater correlation than ratio methods but none was more correlated than others across all four reach methods; thus the Hypothesis 3: BFFR will have greater correlation to the FRCS than the UFFR is rejected.

A Multilinear Regression was also done to determine strength of the 4 reach methods to the FRCS. None of the methods was determined to be statistically significant based on the *P* values, but the short height group had showed a greater statistical significant than the taller groups with ranges of *p* values from 0.397 to 0.401 in the short group to 0.772 to 0.817 in the tall group. However, the strength of impact on the FRCS increases as one gets taller with 0.29 (short), 0.42 (medium) and 0.60 (tall). The bilateral reach methods were slightly more significant than the unilateral reach methods; BFFR: 0.659, BRHR 0.620, compared to UFFR 0.734, URHR 0.795.

Can a ratio be determined for bilateral RHR across all height groups that would improve the ability to identify fall risk compared to the unilateral FFR of 10" as defined by Duncan et. al. (1990)?

Based on the Pearson's multi-correlation, the variations between the fall risk methods used for the FRCS and the 4 reach methods, identified UFFR and the BFFR slightly more correlated with height, the bilateral methods stronger with ABC and FRCS, and all 4 were the were the same with TUG. However, all methods overall were moderately correlated with all the measures except the demographic history. The multilinear regression had no statistical significance of any of the 4 measures however the bilateral methods were slightly greater impact on the FRCS. However, overall the reach to height ratios have not shown an improvement to identify fall risk therefore, Hypothesis 4: The BRHR will increase the likelihood of accurately identifying fall risk when compared to the current unilateral FFR of 10” as cut score is not accepted by this study.

Assessment Research Methodology

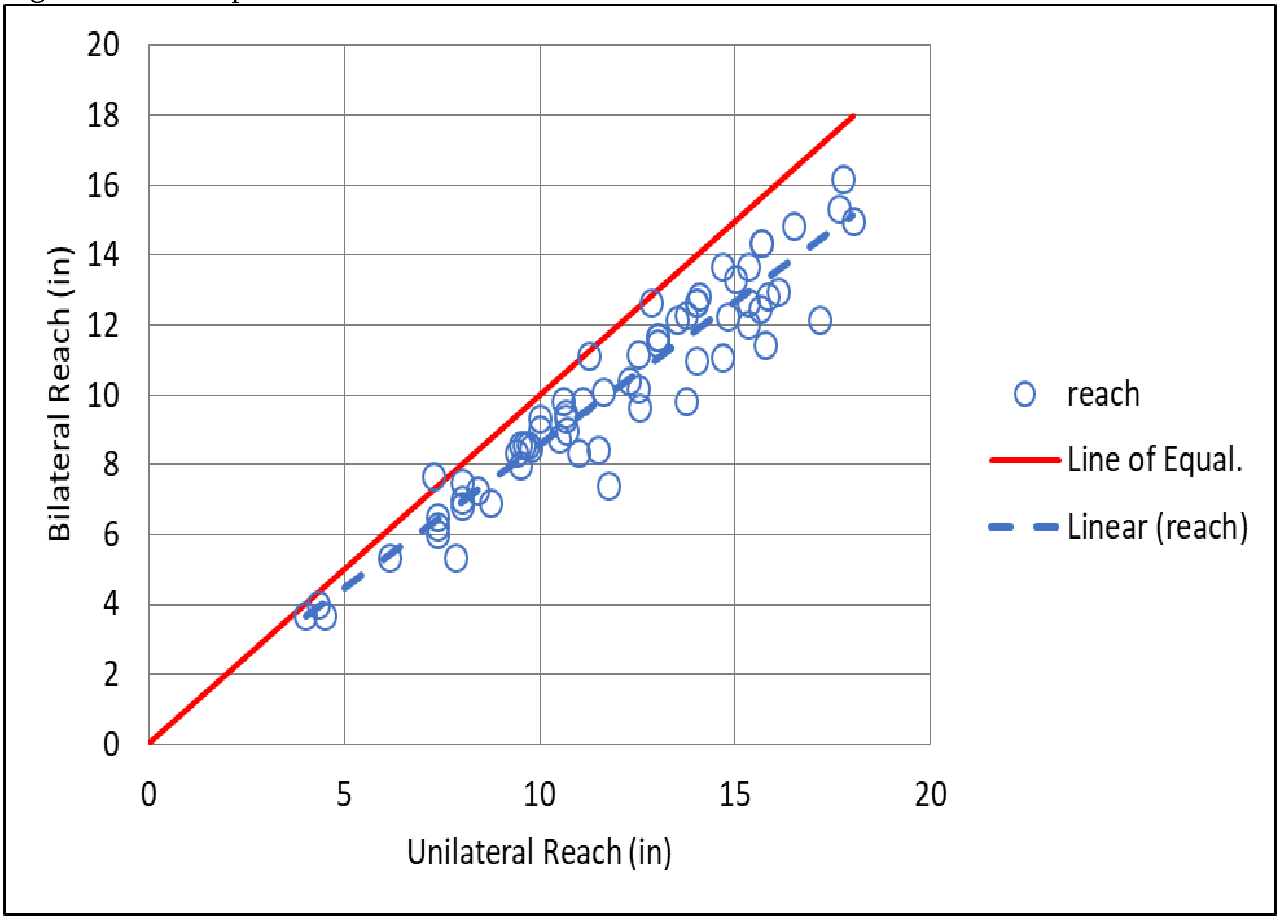
The correlation analysis showed that all four-reach methodologies are highly correlated with each other and moderately correlated with height. The URHR and the BRHR were less correlated to height (0.47 and 0.42 respectively) than the UFFR (0.63) and BFFR (0.59). The between height group analysis had statistically significant differences between the three height groups for all four methodologies (UFFR p=5.7x10^{-6}, URHR p=0.0012, BFFR p=7.8x 10^{-7}, BRHR p=0.00052). The multilinear regression had slightly more influence from the bilateral reach methods (BBFR p=0.659 and BRHR p=0.620) than the unilateral reach methods (UFFR p=0.734 and URHR p=0.795). Reviewing these results, there is no single reach to height ratio that can be determined that would identify fall risk across all 3 height groups. Therefore the use of a reach to height ratio calculation does not improve identification of fall risk with the FFRT.

BFFR performed equal to the UFFR on the correlation to FRCS (0.54) indicating that either could identify fall risk. However, the BFFR had greater statistical difference between groups than UFFR (p=7.8x10^{-7} vs p=5.7x10^{-6}). This indicates the BFFR has larger distance between the height groups potentially being able to identify fall risk by height group cut point values without the potential for overlap in height groups. Therefore, scatterplots were created to determine if the BFFR could improve identification of fall risk

Determining BFFR Cut Points

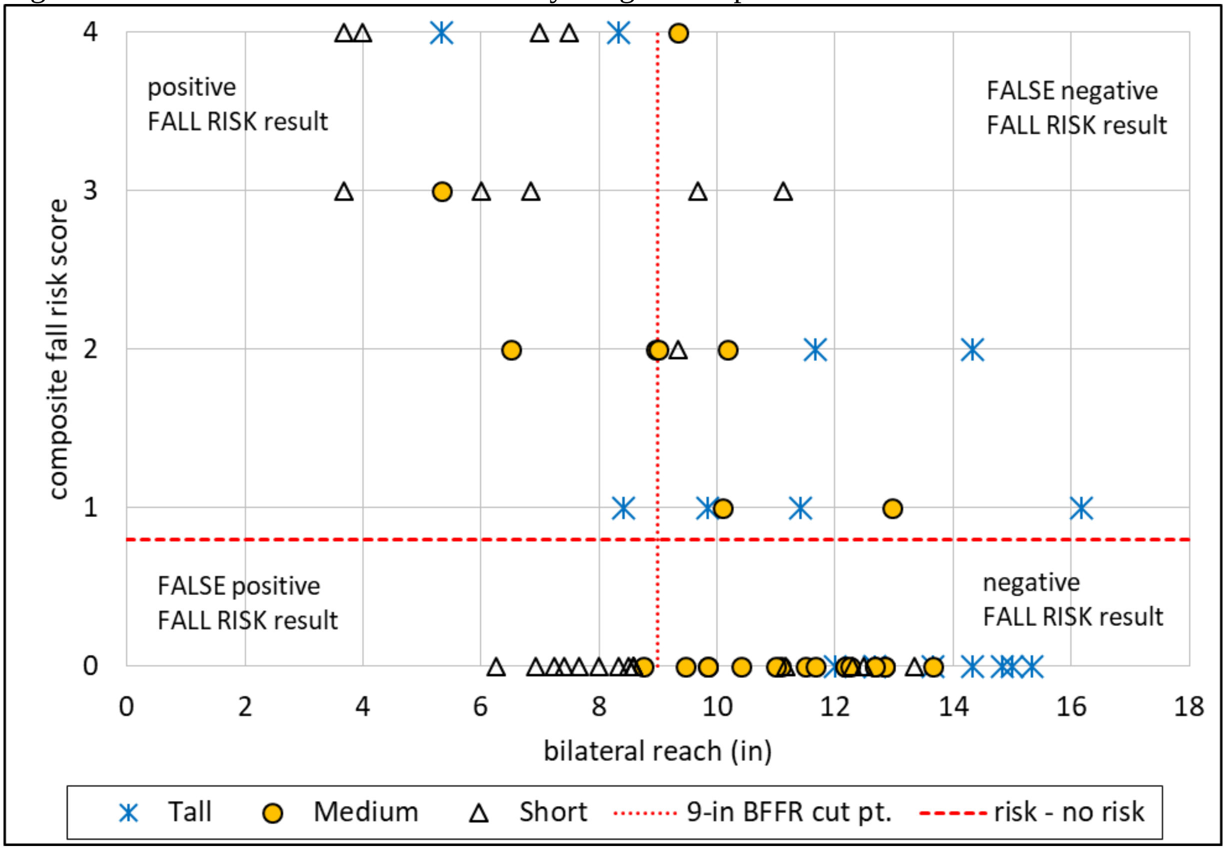
A scatterplot was created (Figure 5.1) comparing the BFFR and UFFR distance. Each circle represents one individual’s bilateral and unilateral reach distance. The dashed linear line is a linear trend line for the data. The 10” cut point for the UFFR (the normative reference for fall risk per Duncan et. al, (1990) on the x-axis intercepts the BFFR at approximately 9 inches on the y-axis. Therefore, for the comparison of the BFFR distance for this study to identify fall risk, 9” cut point was utilized as comparable to the current UFFR standard.

Figure 5.1 Scatterplot of UFFR and BFFR



A scatterplot graph was then developed based on the bilateral reach distance (Figure 5.2). Each height group was identified by a unique symbol and the BFFR 9” cut point for fall risk was added.

Figure 5.2 BFFR 9-inch Cut Point Value by Height Group



The quadrants are marked for those identified as true positive, false positive, true negative and false negative for fall risk based on composite fall risk score. Table 5.2 lists the participants, by group, in each quadrant. Most critical to review is the number of false negatives in the upper right quadrant. There are 12 participants who are at fall risk but not identified by the BFFR with a single cut point value.

Table 5.2 Number of Participants Identified as Fall Risk based on BFFR 9-inch Cut Point by Height Group

Fall Risk Prediction	Short	Medium	Tall	TOTAL
Positive Fall Risk	7	4	3	14
FALSE Positive Fall Risk	11	1	0	12
Negative Fall Risk	4	16	8	28
FALSE Negative Fall Risk	3	4	5	12

Since the BBS utilizes 10” for BFFR for the cutoff for fall risk (Berg et al., 1989b), by moving the BFFR fall risk cut point value 1 inch to the right and further dividing this value as specific values for each height group (10” for short, 11” for medium and 12” for tall height groups), the number of false negative results can be reduced as shown in Figure 5.3. Comparing the false negatives from the original 9” cut point to the number of false negatives based on the adjusted cut point for each height group, the number of false negative results is reduced by 67% in the short group, 75% in the medium group, and 60% in the tall group. There is no change in the number of false positives for the short and tall height groups but there is an increase in false positives for the medium height group by 400%. Regarding true positives, the short group increases by 28%, and the medium group by 75% and the tall group by 100%. Table 5.4 identifies the false negatives, true negatives, true positives and false positives and percentage of change based on height group.

Figure 5.3 Adjusted BFFR Cut Point Value by Height Group

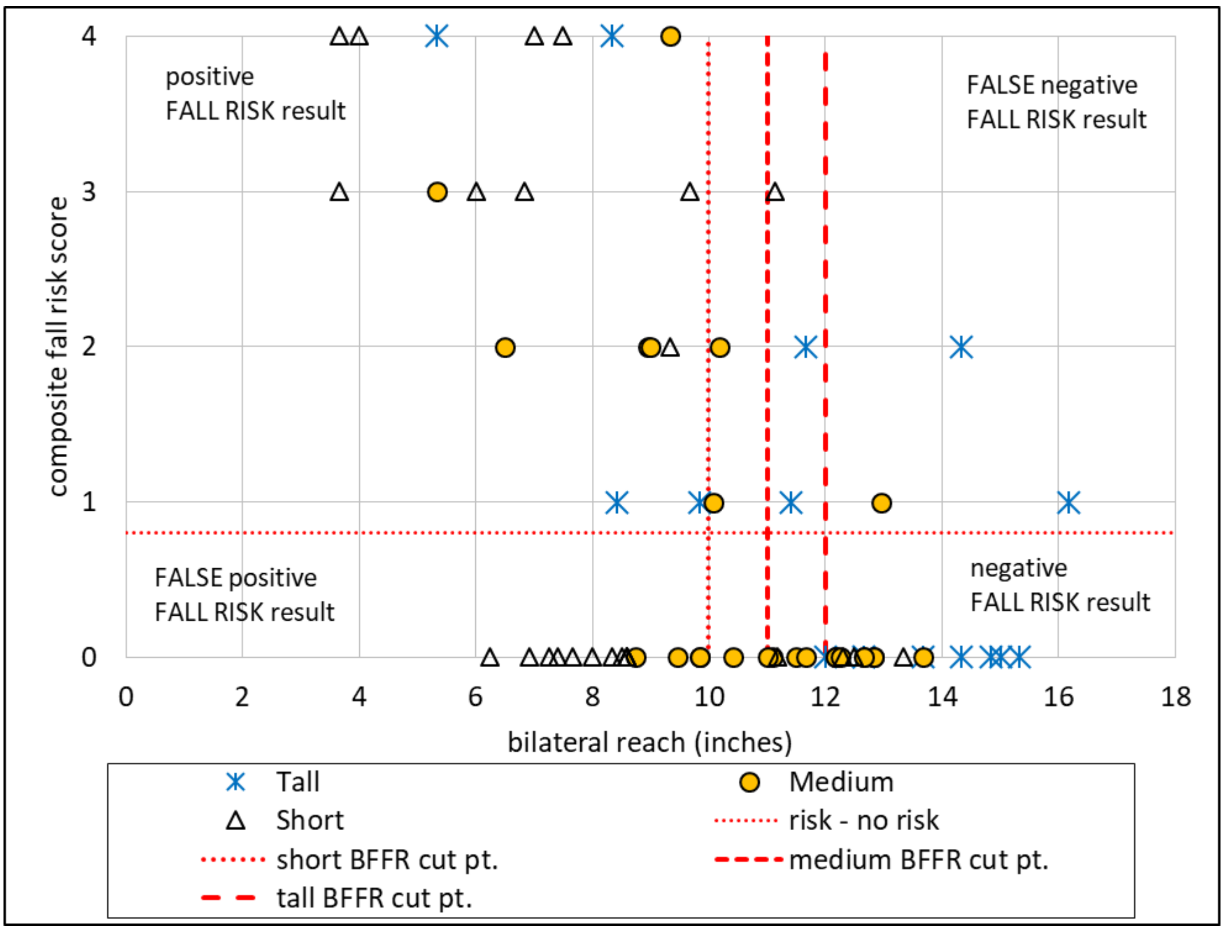


Table 5.3 Fall Risk Identification based on BFFR New Cut Point Values by Height Group with Percent Change from 9-inch Cut Point (Table 5.2)

Fall Risk Prediction	Short	Medium	Tall	TOTAL
Positive Fall Risk	9 (28% incr)	7 (75% incr)	6 (100% incr)	22 (57% incr)
FALSE Positive Fall Risk	11 (no chg)	5 (400% incr)	0 (no chg)	16 (33% incr)
Negative Fall Risk	4 (no chg)	12 (25% decr)	8 (no chg)	24 (14% decr)
FALSE Negative Fall Risk	1 (67% decr)	1 (75% decr)	2 (60% decr)	4 (67% decr)

Summary of Analysis

Statistical differences were found between height groups in the non-fall risk populations for all four reach methods utilized; UFFR p=3.0x10^{-6}, URHR p=1.2x 10^{-3}, BFFR p=7.8x10^{-7}, and BRHR p=5.2x10^{-4}. There is stronger statistical differences with the UFFR and BFFR than with the URHR and BRHR. The larger statistical differences between UFFR and BFFR would indicate a further separation of the measured data between height groups. This greater separation of data between the height groups could enable improved true identification of fall risk and non-fall risk if height cut point values were based on height group classification.

Since the Reach to Height ratio (URHR and BRHR) does not add to the ability for improvement in identifying the fall risk, this extra calculation is not clinically applicable. The Figure 5.3 demonstrate how using the BFFR based on height group classification could improve the identification of fall risk by reducing the false negatives and increasing the true positives. The adjusted cut points in the BFFR, improved the accuracy of the test by reducing the number of false negative predicted fall risk by over 60% in all height groups. This results in less participants are identified as non- fall risk when the FRCS indicated fall risk. This adjusted cut point for BBFR also improved the number of true positives in all groups by 28%, 75%, and 100% (short, medium, and tall, respectively). Reducing the false negatives and increasing the true positives allow participants to be identified for intervention earlier having the potential to reduce falls and injury.

Clinical Implications/Relevance

This study supports the hypothesis that height does affect functional reach; thus questioning the use of the FFRT cut point value of 10” across all height groups. There is a statistical significant difference between all height groups and each of the four reach methods studied: UFFR (p=3x10^{-6}), URHR (p=0.0012), BFFR (p=7.8x10^{-7}), and BRHR (p=0.0052). Based on this study, a single cut point value could not effectively identify fall risk for all three-height groups in any of the measures; thus identification of fall risk should be based on individual cut value score for each height group. Clinicians should be measuring height and including this in their assessment when using a functional reach test. While this study used a stadiometer for consistency, clinicians can use the 3 point contact method against a wall when determining height.

The overall URHR for the older adults identified as fall risk (FRCS >0) was found to be 15.77% which is 4% less than those identified as non-fall risk (FRCS=0). Both the UFFR and the URHR result in higher scores as height increases for both those at fall risk and those non-fall risk. There is found a decline in the URHR with aging, but there is still a statistical difference between height groups (p=0.00123). Based on this statistical difference between height groups, a single percentage of the height that one should be able to reach (URHR) for identifying fall risk across all height groups cannot be identified. Therefore, this study finds that using the URHR does not add anything to the FFRT methodology in identifying fall risk.

The greater statistical difference in the BFFR (p=7.8x10^{-8}) indicates a greater distinct difference between height groups than the BRHR (p=0.00052). Based on this current study, the BRHR does not improve the BFFR for identifying fall risk as there is still a statistical difference so one percentage of reach to height value cannot be determined. Since reach to height ratio did not produce a single ratio (or non- statistical difference between height groups) for either the URHR or the BRHR, the extra calculation of the ratio does not add anything to improve forward reach in identifying fall risk.

The current UFFR criteria of less than 10” was only 64% accurately predicting fall risk for each height group shown in Table 4.6 and 4.7. Having cut point values for fall risk criteria for each height group can reduce the number of false negatives and increase the number of true positives allowing for early identification of those older adults needing interventions. However, using the BFFR to reduce variation of movement reduces the risk of substitutions influencing fall risk identification. The reduction of variations in movement and determining a cut point value for fall risk based on individual height groups, false negatives can be reduced. This would increase the early identification of fall risk for older adults; providing opportunity for early intervention. Based on this study, the recommendation for clinical practice is to utilize the BFFR to reduce movement variations and utilize with cut points of 10” for short height population (<5’5”), 11” for medium height population (5’5” to 5”9”), and 12” for tall height populations (>5’9”) to identify fall risk in older adults.

Limitations

Reliability/Validity Threats

Researchers: The researcher assistants for this study were graduate students in the physical therapist education program at Alabama State University. Each assistant was instructed and tested by the primary researcher for their specific task and only assisted in the data collection of the fall risk measures and initial inclusion criteria of vital signs, height measurement and standing ability. These students utilized the script as outlined for each task in the Appendices G-K, were assigned only one task, and were supervised by the primary researcher. However, intra-rater error could have occurred affecting the FRCS. If a graduate student did not accurately perform their assigned measure, the participant could have been falsely identified as fall risk or non-fall risk based on that measure. Since each measure was part of the calculated FRCS, any one measure could alter a participant's score thereby influencing analysis.

Researcher bias may also have occurred between primary researcher and assistants as all data collection took place in one large community room. This enabled all researchers to observe all data collection and none were blinded to the patients' heights based on visual observation. The primary researcher collected all data on the four FFR methods and was not blinded to group assignment (short, medium, tall) which could have led to measurement error/bias. To control bias during data collection, research assistants at each task station did not have access to all data of any participant. Once all collection was completed, the primary researcher performed all data entry and analysis. To reduce the risk of researcher error, two outside research experts reviewed the data spreadsheets to double check data entry and performed their own analysis for comparison.

Sample Size. A sample size of 68 was determined as needed for the effect size for this study with goal for recruitment being 75, 25 for each height group. The study was able to recruit 66 participants, which still produced a large effect size. However, this study was done at only one center in Montgomery, Alabama, which limits generalization to other geographic/ethnic populations. The reduced number of participants in the tall height group also provides an imbalance when comparing across height groups.

Participants. The sample size of 25 per height group was not initially obtained. A second recruitment was needed especially for the tall height group. This may have affected base line as the researcher and assistants were personally asking participants versus recruitment in large groups.

The older adults at this Center have participated in health education fairs with these researchers and other students, faculty and staff from Alabama State University. The Hawthorne effect may have played a part in the study, especially with the ABCs, as the participants may have wanted to "please" the research assistants and primary researcher whom many had met previously at these other events by providing answers they think are wanted. All attempts were made to make sure each participant was provided full opportunity to answer honestly to all questions.

The baseline differences between the height groups regarding fall risk may have affected the study. Fall risk was not equally spread across the different height groups regarding which fall risk measure was the identifier. Each measure utilized are identified as fall risk measures by the AGS (as discussed in Chapter 2); however, each one does not predict fall risk equally. With the Multilinear Regression, TUG was found to be the best predictor of fall risk based on FRCS when examining the entire sample, but TUG was not the best predictor across each height group nor was fall risk based on TUG equally divided across height groups. The number in the tall height group was also smaller than the other groups. To adjust for these baseline differences, each height and age group was averaged within group before comparison between groups. For this study, there were no participants who had a composite fall risk score of zero in the medium and tall height groups over the age of 69 year. The overall number of fallers based on the composite score was 26 versus the number of non-fallers being 40. The number of fallers and non-fallers in the tall height group was equal but due to the smaller number of participants in the tall height group, this may not be representative of this population.

Fatigue of the participants may have also influenced the study based on the number of tasks required for each participant to perform. Since the four reach methodologies required the participant to stand, the outcome measures were purposely chosen to allow sitting tasks (grip strength and ABC) and standing tasks (TUG) to reduce the impact of fatigue. Water and rest breaks per individual participant's request were implemented to attempt to reduce the risk of fatigue.

The planned methodology as discussed in Chapter 3, to reduce waiting time (and thus time commitment) of each participant, each task was not performed in any specific order for Part 2 of the study. This was also done to ensure that any one task did not affect the next task nor that any one task might be influenced by fatigue factor if all had done the tests in a specific order. However, randomization of the order the tasks would have been better to ensure that each task had equal opportunity to be done in each order sequence.

Fall Risk Composite Score. The FRCS was based on each fall risk measure outcome predicted fall risk equally. Each fall risk measure to compute this are measures recommended in the AGS guidelines for use with aging adults on an annual basis (AGS, 2011). While fall risk on each one of these measures is considered fall risk and the individual referred for full assessment (AGS, 2011), the FRCS was a summation of each one of these measures identified as fall risk (1) or non-fall risk (0). This gave a score of 0-4 for larger viewing on graphs. However, to ensure that the AGS guidelines were followed regarding any of the measures being a fall risk identifier, any individual with a score of 1 or higher was considered fall risk for the statistical analysis. Using other fall risk measures recommended by the AGS, such as gait speed, single leg stand or sit to stand, could give different results.

Outcome Measures Utilized. This study utilized four fall risk measures from the AGS Guidelines (2010, 2011), as discussed in Chapter 2; TUG, grip strength, self-reported ABC, and demographic history for comparison with the 4 reach methods. The computed FRCS weighted the 4 outcome measure from AGS Guidelines as equally contributing to identifying fall risk by using the dichotomy of 0 or 1 (non-fall or fall risk) for each measure. Three of the measures (TUG, Grip and ABC) are predictors of future falls, whereas the demographic history is based on actual history of falls and decline. Based on the correlation matrix, TUG had a high correlation to the FRCS in the overall population, but having only18 out of the 66 participants identified as fall risk by TUG limits generalization to other populations. ABC had the next high correlation to FRCS but only had 14 out of the 66 participants identified as fall risk. Both also varied within each height group. Therefore, the

FRCS giving equal weight to all measures may have affected the overall results. The small percentage of fall risk identified by each measure in the overall population and in each height group limits generalization beyond this study. As stated, using the FRCS as a composite of selected measures was accounted for by identifying anyone as having a FRCS of 1 or greater to be considered fall risk; thereby following AGS guidelines (2011) that any one tool should be referred for full assessment.

Future Studies

Future studies should have a larger sample size and multisite sampling to ensure greater generalization of results. This study had only African American and Caucasian participants and had limited participants in the taller groups; especially in older age group. A multisite study could increase the sampling in the taller groups as well as determine if there is ethnic differences. A larger sample would increase the confidence level of the outcomes. Multisite collection will also reduce the tendency for the sample population having a relationship with the researchers which could bias the study based on the Hawthorne Effect.

The outcome measures utilized for comparison to the BFFR should be randomized for the participants to perform. This will ensure that one measure is not influencing the next and that all measures are truly randomized in each location of order of performance.

The research assistants should be tested by outside testers to ensure reliability. This testing should also include inter rater reliability and intra rater reliability to ensure accuracy of measurement. One way to consider this is to use only those therapists who have taken the Academy of Geriatric PT course on Certified Exercise Expert for Aging Adults which has a practical testing component of the outcome fall risk measures. This would limit potential research sites, so another credential could be to use only those with the Geriatric Clinical Specialist Certification.

Data should be entered for analysis separate from the height groups to ensure objectivity. After all data is entered by one researcher, another researcher could identify the height group designation while be blinded to the outcome measure data.

Future studies may also consider other outcome fall risk screening measures for comparison. Lusardi et al. (2017) suggested that besides the history and self-reported confidence of an individual, based on post-test probability of predicting falls, the TUG, five times sit to stand, single leg stand, and gait speed could be used to enhance the identification of those who are and are not at risk for falls. Using these measures in relation to the BFFR cut values determined by this study in relation to height groups (short 10", medium 11", tall 12") would determine the validity of this study.

Other factors to consider when developing future research in relation to FFR include; physiological changes with aging and effect on BFFR, can BFFR predict falls not just identify fall risk, what other body factors affect FFR including Body Mass Index (and if body mass is more abdominal than extremity), leg/trunk length relationship, or foot size, and finally how do the body factors affect reaching in other directions.

Conclusion

This study confirms the hypothesis that height is correlated to the reaching ability in older adults. A statistical significant difference was found between the three height groups and all four reach methods; UFFR, BFFR, URHR and BRHR. This indicates that the FFRT should account for height differences when identifying fall risk and not a single value of 10" for all height groups. There was also a moderate correlation (0.6-0.8) between all 4 reach methods and the fall risk measures used for this study; TUG, ABC, Grip Strength and demographic history/fall history. The Reach to height ratio did not add to the identification of fall risk so the extra calculation is not necessary for clinical usage. However, the BFFR had slightly better performance than the UFFR so with the scatterplot, scores were found for each height group that reduced the false negative and false positives in identifying fall risk. Therefore, the BFFR should be utilized to identify fall risk by using the cut point values based on height that utilizes 10” for those <5’4”, 11” for those 5’4” to 5’9”, and 12” for those >5’9”, which could improve identification of fall risk. By improving identification of fall risk with the BFFR, early interventions can be implemented to reduce the fall prevalence in aging adults.

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APPENDIX A

NOVA SOUTHEASTERN UNIVERSITY
Institutional Review Board

To: Jill Heitzman
Dr. Pallavi Patel College of Health Care Sciences

From: Nurit Sheinberg, Ed.D.
Chair, Institutional Review Board

Date: December 7, 2017

Subject: IRB Initial Approval Memo

TITLE:
Can Bilateral Forward Functional Reach Distance as a Percentage of an Individual's Height Impro ve the
Predictability of Fall Risk Versus the Standard Unilateral Forward Functional Reach Distance Normative Val ues?–
NSU IRB Protocol Number 2017-695

Dear Principal Investigator,

Your submission has been reviewed and approved by the Institutional Review Board under Expedited review proce dures
on December 7, 2017. You may proceed with your study.

Please Note: Stamped copies of all consent, assent, and recruiting materials indicating approval date must be used when
recruiting and consenting or assenting participants.

Level of Review: Expedited

Type of Approval: Initial Approval

Expedited Review Category: Expedited Category 4
Expedited Category 7

Level of Risk: Minimal Risk

Continuing Review: Continuing Review is due for this protocol on December 6, 2018. A continuing review (progress report) must be submitted one month prior to the continuing review date.

Changes: Any changes in the study (e.g., procedures, consent forms, investigators, etc.) must be approved by the I
RB
prior to implementation using the Amendment Form.

Post-Approval Monitoring: The IRB Office conducts post-
approval review and monitoring of all studies involving humanarticipants under the purview of the NSU IRB. The P
ost-Approval Monitor may randomly select any active study for a
Not-for-Cause Evaluation.

Final Report: You are required to notify the IRB Office within 30 days of the conclusion of the research that the stud
y has
ended using the IRB Closing Report Form.

Your study was approved under the following criteria:

- Consent Participants according to criteria of 45 CFR 46.116 and 45 CFR 46.117

Translated Documents: No

Please retain this document in your IRB correspondence file.

CC: William Smith, JD
Rose Colon, PhD

Jennifer Canbek, PhD

APPENDIX B

City of Montgomery, Alabama

Todd Strange

Mayor

June 20, 2017

Jill Heitzman

Interim Program Director

Associate Professor

PT Program/College of Health Services

Alabama State University

John Buskey Building

1155 N. University

Montgomery, Alabama 36101

RE: Acceptance of ASU Students

The Crump Senior Center gladly agrees to allow Alabama State University Physical Therapy students and faculty to come to the center for health screens, educational classes, research data collection (as approved by ASU IRB) and other activities mutually agreed upon. The Crump Center participants will sign individual consent forms to participate as per ASU protocol. Neither the Crump Center, ASU, nor participants would receive any financial payment for these activities performed by the ASU students or faculty.

Crump Center looks forward to a rewarding relationship with ASU that will be mutually beneficial for both students and seniors.

In Appreciation,

Mike McGuire

Crump Center Director

APPENDIX C

Recruitment Script

The researcher will announce:

We would like to discuss your participation in a research project being done by Alabama State University and NOVA Southeastern University. Please stay for a few minutes after class if you are interested in participating.

Once gathered:

We are wanting participants to help us determine methods to identify fall risk in the older population. We will be doing the study on the next few Fridays starting at 10:00AM. Your participation is fully voluntary and you may withdraw at any time. Choosing to participate or not will not affect your relationship with either university nor with the Crump Center. The total time you will be needed for this project is 35 minutes. All activities will be done in one session.

The test will consist of you completing 2 forms. One is on your general health and one is a questionnaire on how confident you are performing various tasks in your everyday life. A researcher will be available to answer any and all questions.

After completing these forms, your blood pressure and heart rate will be measured. Then you will be measured for your height and weight.

The next steps include you standing for 1 minute without holding onto anyone or anything. Then you will be asked to sit in a chair and walk 10 feet to a line and back to the chair. The next task is done with your sitting in a chair and squeezing a device with each hand as hard as you can. The final task is with you standing by a wall and reaching forward as far as you can without falling

If you agree to participate you will be asked to sign a consent form. This will allow the information collected to be utilized in reporting the research results. Again, you can withdraw at any time.

If you are interested, Please sign up on the forms we have available here. If you want further information you can contact Dr. Jill Heitzman at Jheitzman@alasu.edu or by phone at 334-2295614.

Thank You, I will be around to answer any questions

APPENDIX D FORM OF WRITTEN CONSENT

You are invited to participate in this study. This study uses common balance tests for older adults to assist in determining fall risk.

If you decide to participate in the study, you will be asked to complete a few forms. These include a medical and personal history. A few questions will be asked on how confident you are in doing daily activities without falling. You will have your height, blood pressure, heart rate and respiration measured prior the activities. Four tests evaluating your ability to stand and walk will be done. You will be asked to stand in one place for two minutes without holding onto support surface. You will be timed getting up from a chair, walking in a straight path, turning around, and walking back to the chair to sit. Your strength will be measured by squeezing a device. Your balance will be measured by reaching forward with one and two arms while standing. All forms and tests will be completed in one 30 minute session.

You will not receive any treatment during this study.

There is minimal risk during this study. Some effects could include fatigue, muscle soreness, and falling during testing. All attempts will be made to keep you safe during the test. Breaks between tasks will be taken as needed for your safety. In case of injury, assistance will be provided by the researcher. The researcher is licensed as a physical therapist in the State of Alabama. If further medical attention is needed, emergency responders will be contacted.

Any information that identifies you specifically will remain confidential. This information will be disclosed only with your permission. Your signature provides permission for use of your age, gender, and the outcomes of each of your tests when reporting the study's results.

Recordings, videos, or photographs will not be taken during this study.

You will receive no compensation for your participation in this study.

Your decision to participate will not jeopardize your future relations with Alabama State University or the Crump Center. You are free to discontinue participation. You may withdraw your consent at any time, without penalty.

If you have any further questions about the study, feel free to contact Dr. Jill Heitzman at jheitzman@alasu.edu

YOU ARE MAKING A DECISION WHETHER OR NOT TO PARTICIPATE. YOUR SIGNATURE INDICATES THAT YOU HAVE DECIDED TO PARTICIPATE HAVING READ THE INFORMATION PROVIDED ABOVE.

Participant's Signature_________________________________Date______________

Witness _________________________________ **Date**_____________

APPENDIX E

Sign up form (multiple forms will be made for the dates approved by Crump Center once IRB approved)

Date	Name	Contact information (phone)
10:00 AM		
10:30 AM		
11:00 AM		
11:30 AM		
12:30 PM		
1:00PM		
1:30 PM		
2:00PM		
2:30PM		
3:00PM		

APPENDIX F **Test Outcomes Date Form**

Participant Number______________ Able to stand 2 minute unassisted (y/n)_______

TEST	Score or Pre score	Post score
Height (barefoot)		
BP		
Heart Rate		
Respiration		

TUG : Use of assistive device (Y/N) _______ Type _________________

Practice trial	Measured Trial

Grip Strength (kg): Dominant hand ________________

	Trial 1	Trial 2	Trial 3
Right hand			
Left hand			

Calculation: average grip/weight: R_____________ L ________________

Functional Reach: Dominant side _____________

Unilateral:

Practice 1	Practice 2	Trial 1	Trial 2	Trial 3

Average of the 3 trials: __________________ Reach/Height:___________________

Bilateral:

Practice 1	Practice 2	Trial 1	Trial 2	Trial 3

Average of the 3 trials:______________ Reach/height: ________________

ABC score___________________________

Fall history/demographic risks:_______________________

APPENDIX G

HEIGHT

Equipment:

Portable Stadiometer stand

Purpose:

Measurement of height during best posture position

Procedure:

1. Have the participant remove their shoes.
2. Assist the participant to step up onto the stadiometer stand
3. Have them stand as straight and tall as possible
   "Please stand as tall as possible while looking forward"
   a. Watch for substitution: arching lumbar region, extending neck
4. Bring the long arm of the stadiometer to touching the top of the participant's head (not hair)
5. Record the measurement seen on the stadiometer
6. Assist the participant off the stand, sit down and help them put on their shoes

Short <5'5", Medium 5'5" to 5'9", Tall >5'9"

APPENDIX H **Demographic/History information** Participant number__________

Age: ______ Ethnicity: _______________ Gender: Male Female

Emergency Contact: ______________________Number: ___________________

1. **Do you use any of the following devices to walk in the home?**

___cane ___walker ___crutches ___none used in the home

2. **Please check any medical condition currently (or in the past 5 years) being treated by a medical provider**

__High blood pressure	__Total joint replacement
__Heart disease	__Balance disorder
__Diabetes	__Pulmonary problems
__Stroke	__Cancer
__Heart attack	__Seizure disorders
__Parkinson disease	__ Other: Please list

3. **Do you EXERCISE on a regular basis?** Yes ____ No_____

Type of exercise: ______________________Frequency: ______________________

4. **Please answer the following questions: (Yes or NO)**

_____During the past month, have you often been bothered by feeling down, depressed or hopeless?

_____ During the past month have you often been bothered by little interest or pleasure in doing things?

5. Have you fallen:

in the last month? _____, last 3 months? ______, last year?________

If so, were you injured to require medical attention? __________________

6. Do you know any reason why you should not do any physical activity?

No______ Yes____, please state why______________________

APPENDIX I ACTIVITIES-SPECIFIC BALANCE CONFIDENCE (ABC) SCALE

Verbal instructions to the participants: "For each of the following questions, please indicate your level of confidence in doing the activity without losing your balance or becoming unsteady from choosing one of the percentage points on the scale from 0% to 100%. If you do not currently do the activity in question, try and imagine how confident you would be if you had to do the activity. If you normally hold onto someone or to something to do the activity, rate your confidence as it you were using these supports. If you have any questions about answering any of these items, please ask."

The research assistant will then read each question to the participant and circle the answers given by the participant.

Scoring instructions: The ABC is an 11-point scale and ratings should consist of whole numbers (0-100) for each item. Total the ratings (possible range = 0 – 1600) and divide by 16 to get each subject's ABC score.

0% 10 20 30 40 50 60 70 80 90 100%

no confidence completely confident

How confident are you that you will not lose your balance or become unsteady when you…

1. **…walk around the house?** 0% 10 20 30 40 50 60 70 80 90 100%
2. **…walk up or down stairs?** 0% 10 20 30 40 50 60 70 80 90 100%
3. **…bend over and pick up a slipper from the front of a closet floor?** 0% 10 20 30 40 50 60 70 80 90 100%
4. **…reach for a small can off a shelf at eye level?** 0% 10 20 30 40 50 60 70 80 90 100%
5. **…stand on your tiptoes and reach for something above your head?** 0% 10 20 30 40 50 60 70 80 90 100%
6. **…stand on a chair and reach for something?** 0% 10 20 30 40 50 60 70 80 90 100%
7. **…sweep the floor?** 0% 10 20 30 40 50 60 70 80 90 100%
8. **…walk outside the house to a car parked in the driveway?** 0% 10 20 30 40 50 60 70 80 90 100%
9. **…get into or out of a car?** 0% 10 20 30 40 50 60 70 80 90 100%
10. **…walk across a parking lot to the mall?** 0% 10 20 30 40 50 60 70 80 90 100%
11. **…walk up or down a ramp?** 0% 10 20 30 40 50 60 70 80 90 100%
12. **…walk in a crowded mall where people rapidly walk past you?** 0% 10 20 30 40 50 60 70 80 90 100%
13. **…are bumped into by people as you walk through the mall?** 0% 10 20 30 40 50 60 70 80 90 100%
14. **… step onto or off an escalator while you are holding onto a railing?** 0% 10 20 30 40 50 60 70 80 90 100%
15. **… step onto or off an escalator while holding onto parcels such that you cannot hold onto the railing?** 0% 10 20 30 40 50 60 70 80 90 100%
16. **…walk outside on icy sidewalks?** 0% 10 20 30 40 50 60 70 80 90 100%

A score of <67% will be used to classify fall risk (Reelick, 2009)

APPENDIX J

Handgrip Strength

Equipment:

Hand grip dynamometer, chair with armrests

Purpose:

Measure the strength of hand grip. Has been shown to be predictive of future disability, mortality and postoperative complications

Procedure:

1. Patient sits in a chair with arm resting on armrest of chair.
2. Arm is positioned in shoulder neutral, elbow flexed to 90 degrees, forearm in neutral and wrist in 0-30 degrees of extension and just over the end of the armrest
3. Dynamometer is put in the second hand position
4. Patient is instructed to squeeze as hard as possible for 3 seconds or until the needle stops rising when giving encouragement to squeeze harder
    a. "Please squeeze as hard as you can until I tell you to stop"
    b. "OK, Squeeze, squeeze, squeeze, keeping squeezing" Stop will be said at the 3 second mark.
5. Alternate sides testing each side for 3 trials each (6 in total)
6. Record the maximum of the 3 trials for each hand (maximum of all 6 trials is used when determining decline to frailty)

Less than 16 kg for females, 26 kg for males is indicative of functional decline.

(Bohannon R, 2015)

APPENDIX K TIMED UP AND GO (TUG) PROTOCOL

Equipment:

-A three meter (10') distance marked with tape

-Standard chair of 18 inches height with armrest

-Stopwatch

Procedure:

- Have the subject wear closed-toe shoes that they use on a daily basis.

-Have the subject sit in the chair with their back against the chair and their arms resting on the armrest.

-Provide the following verbal instructions:

> "When I say 'go' I want you to stand up and walk along the mat to the green line, turn and then walk back to the chair and sit down again. Walk at your normal pace."

- Allow one practice trial before being timed in order for the participant to become familiar with the test.

- No physical assistance is provided

- Record time, which begins once "go" is said and stops once subject sits back down in chair.

Instructions to the patient:

"When I say 'go' I want you to stand up and walk to the line, turn, and then walk back to the chair and sit down again. Walk at your normal pace."

Podsiadlo D, Richardson S. The timed "up and go": a test of basic functional mobility for frail elderly persons. JAGS 1991; 39: 142-148.

Fall risk: >9.05s for 60-64

>9.77 for 65-69

> 9.96 s for 70-79

> 10.80s for >80

APPENDIX L

Functional Reach

Equipment:

Grid paper affixed to wall, tape line on the floor, ruler

Purpose:

Identify fall risk in an anterior/posterior plane of movement

Procedures:

1. Using a the grid paper mounted on the wall at shoulder height, ask the subject to position themselves close to, but not touching the wall with their arm outstretched and hand fisted. Make sure they are not already protracting or retracting the scapula prior to starting.

2. First test will be the unilateral reach of 2 practice then 2 measured trials using the following procedures

   A. Mark the starting position by marking on the grid paper where the 2nd MCP joint line up with on the yardstick. Have the subject reach as far forward as possible in a plane parallel with the measuring device **Instructions to the patient:**

"Please reach as far forward as you can without losing your balance. Keep your feet on the floor. You are not allowed to touch the wall or the ruler as you reach. You will have two practice trials and then I will record the distance that you reach forward."

   B. Mark the end position of the MCP joints against the grid paper, and measure the difference between the starting and ending position marks

3. They are free to use various reaching strategies.

4. If they move their feet, touch the wall or lose their balance that trial must be discarded and the trial repeated.

5. Guard the subject as well as have a gait belt around them as the task is performed to prevent a fall.

These same procedures will be repeater for the bilateral reach, however both arms are raised keeping fists at same level and together while reaching forward.

**Duncan P, Weiner D, Chandler J, et al. Functional reach: a new clinical measure of balance. J of Gerontol 1990; 45: M192-197.*

APPENDIX M
DATA

Participant No.-Gender	Gender Catergory (1) male (2) female	Age	Age Category (1) 60-69 (2) 70-79 (3) 80+	medical info	assist device? (1) yes (0) no	exercise	race	Height	Height Category (1) short (2) medium (3) tall	demographic fall risk	ABC score	ABC fall risk	Tug time	Tug fall risk	grip strength Rt. (1)	grip strength Rt. (2)	grip strength Rt. (3)	grip Right Average	grip strength Lt. (1)	grip strength Lt. (2)
UNITS:		years						inches		y=1 n=0	(0-100)	y=1 n=0	seconds	y=1 n=0	pounds	pounds	pounds	pounds	pounds	pounds
1-female	2	70	2	asthma, arthritis	0	5x/wk	cauc	63	1	0	99	0	9.0	0	27	28	25	26.7	16	23
2-female	2	67	1	anemia	0	2x/wk	cauc	69	2	0	94	0	7.7	0	22	23	23	22.7	20	22
3-female	2	72	2	HTN, TKA, DM, CA	0	1-2x/wk	AA	52	1	1	56	1	12.9	1	23	24	22	23.0	24	22
4-female	2	74	2	HTN, TSA	0	1x/wk	AA	62	1	0	77	0	7.4	0	24	16	24	21.3	16	18
5-female	2	66	1	HTN, AR	0	none	cauc	67	2	0	91	0	8.5	0	34	30	29	31.0	28	26
6-female	2	64	1	HTN, Knee pain, dizziness	0	none	AA	64	1	1	23	1	14.5	1	28	20	26	24.7	20	16
7-female	2	75	2	HTN, gout, DM	0	none	cauc	61	1	0	84	0	9.7	0	36	36	37	36.3	37	36
8-female	2	75	2	HTN, MI, arthritis,THA	0	3x/wk	cauc	64	1	0	94	0	9.7	0	24	23	25	24.0	20	25
9-female	2	74	2	asthma, arthritis	0	3x/wk	AA	63	1	0	93	0	8.8	0	31	32	28	30.3	34	34
10-male	1	66	1	HTN, dizziness	0	6x/wk	cauc	77	3	1	99	0	5.2	0	49	54	58	53.7	56	56
11-female	2	65	1	HTN, asthma	0	3x/wk	cauc	62	1	0	88	0	6.7	0	18	18	20	18.7	18	19

Participant No.-Gender	grip strength Lt. (3)	grip Left average	grip fall risk	unilateral reach (1)	unilateral reach (2)	unilateral reach (3)	unilateral reach average	Unilateral fall risk <10"	unilateral reach to height ratio	bilateral reach (1)	bilateral reach (2)	bilateral reach (3)	bilateral reach average	bilateral reach to height ratio	combined fall risk score
UNITS:	pounds	pounds	y=1 n=0	inches	inches	inches	inches	y=1 n=0	%	inches	inches	inches	inches	%	
1-female	24	21.0	0	9.8	9.0	10.0	9.6	1	15.2	9.0	8.8	8.0	8.6	13.6	0
2-female	19	20.3	0	14.0	15.3	15.1	14.8	0	21.4	11.8	12.3	12.8	12.3	17.8	0
3-female	22	22.7	0		6.3	8.5	7.4	1	14.2	6.0	6.0	6.0	6.0	11.5	3
4-female	18	17.3	0	10.0	9.8	9.5	9.8	1	15.7	9.0	8.5	8.0	8.5	13.7	0
5-female	25	26.3	0	16.3	15.8	15.5	15.8	0	23.6	11.8	13.3	13.5	12.8	19.2	0
6-female	21	19.0	0	12.3	12.5	12.9	12.5	0	19.6	8.8	10.0	10.3	9.7	15.1	3
7-female	35	36.0	0	7.0	7.5	7.4	7.3	1	12.0	7.5	7.8	7.8	7.7	12.6	0
8-female	25	23.3	0	9.3	9.8	9.5	9.5	1	14.8	8.0	8.3	7.8	8.0	12.5	0
9-female	30	32.7	0	9.3	9.5	9.8	9.5	1	15.1	9.0	8.5	8.3	8.6	13.6	0
10-male	57	56.3	0	16.0	15.5	15.8	15.8	0	20.5	10.8	12.5	11.0	11.4	14.8	1
11-female	19	18.7	0	7.9	7.3	7.0	7.4	1	11.9	5.5	6.6	6.6	6.3	10.1	0

Participant No.-Gender	Gender Catergory (1) male (2) female	Age	Age Category (1) 60-69 (2) 70-79 (3) 80+	medical info	assist device? (1) yes (0) no	exercise	race	Height	Height Category (1) short (2) medium (3) tall	demographic fall risk	ABC score	ABC fall risk	Tug time	Tug fall risk	grip strength Rt. (1)	grip strength Rt. (2)	grip strength Rt. (3)	grip Right Average	grip strength Lt. (1)	grip strength Lt. (2)
UNITS:		years						inches		y=1 n=0	(0-100)	y=1 n=0	seconds	y=1 n=0	pounds	pounds	pounds	pounds	pounds	pounds
12-female	2	66	1	HTN, heart murmur, dizziness,DM, anemia	0	none	AA	66	2	1	66	1	9.3	0	22	28	31	27.0	28	28
13-male	1	77	2	dizziness	0	daily	cauc	72	3	1	93	0	5.9	0	38	36	40	38.0	37	38
14-female	2	78	2	stroke, neuropathy, TSA, DM	1	3x/wk	cauc	62	1	1	97	0	10.9	1	13	15	14	14.0	13	14
15-female	2	78	2	HTN, Breast CA, DM	0	3x/wk	cauc	64	1	1	88	0	10.9	1	14	16	17	15.7	16	16
16-female	2	78	2	arthritis	0	3x/wk	cauc	65	2	0	94	0	6.3	0	26	25	27	26.0	21	21
17-female	2	70	2	HTN< arthritis	0	no	AA	62	1	0	83	0	8.1	0	14	18	23	18.3	20	22
18-female	2	72	2	HTN, heart murmur	0	2x/wk	AA	66	2	0	47	1	13.8	1	23	26	26	25.0	22	24
19-female	2	66	1	HTN, heart murmur, asthma,arthritis	0	2x/wk	AA	68	2	0	96	0	8.2	0	34	38	42	38.0	42	42
20-female	2	64	1	DM, hysterectomy	0	3x/wk	caus	60	1	0	90	0	7.3	0	25	20	17	20.7	22	15
21-female	2	65	1	Heart murmur, anemia, thryroid	0	5x/wk	AA	68	2	0	100	0	9.7	0	33	35	32	33.3	30	30
22-female	2	78	2	HTN,	0	3x/wk	cauc	65	2	0	22	1	15.5	1	26	22	21	23.0	27	23

Participant No.-Gender	grip strength Lt. (3)	grip Left average	grip fall risk	unilateral reach (1)	unilateral reach (2)	unilateral reach (3)	unilateral reach average	Unilateral fall risk <10"	unilateral reach to height ratio	bilateral reach (1)	bilateral reach (2)	bilateral reach (3)	bilateral reach average	bilateral reach to height ratio	combined fall risk score
UNITS:	pounds	pounds	y=1 n=0	inches	inches	inches	inches	y=1 n=0	%	inches	inches	inches	inches	%	
12-female	30	28.7	0	12.5	12.8	12.3	12.5	0	18.9	10.9	10.3	9.5	10.2	15.4	2
13-male	36	37.0	0	18.5	18.0	16.8	17.8	0	24.7	16.5	15.5	16.5	16.2	22.5	1
14-female	15	14.0	1	5.0	3.8	3.3	4.0	1	6.5	5.0	3.8	2.3	3.7	5.9	3
15-female	15	15.7	1	11.3	11.0	11.5	11.3	0	17.6	11.3	11.0	11.1	11.1	17.4	3
16-female	21	21.0	0	15.0	14.5	14.5	14.7	0	22.6	10.3	11.5	11.5	11.1	17.1	0
17-female	21	21.0	0	11.5	12.0	11.8	11.8	0	19.0	7.0	7.5	7.8	7.4	12.0	0
18-female	22	22.7	0	9.5	10.6	12.0	10.7	0	16.2	8.5	9.5	8.9	9.0	13.6	2
19-female	46	43.3	0	14.0	13.0	13.5	13.5	0	19.9	11.0	12.5	13.0	12.2	17.9	0
20-female	16	17.7	0	8.0	8.3	9.0	8.4	1	14.0	7.0	7.5	7.3	7.3	12.1	0
21-female	31	30.3	0	17.5	17.5	16.5	17.2	0	25.2	12.0	13.0	11.5	12.2	17.9	0
22-female	20	23.3	0	7.1	8.5	6.5	7.4	1	11.3	6.5	6.5	6.5	6.5	10.0	2

Participant No.-Gender	Gender Catergory (1) male (2) female	Age	Age Category (1) 60-69 (2) 70-79 (3) 80+	medical info	assist device? (1) yes (0) no	exercise	race	Height	Height Category (1) short (2) medium (3) tall	demographic fall risk	ABC score	ABC fall risk	Tug time	Tug fall risk	grip strength Rt. (1)	grip strength Rt. (2)	grip strength Rt. (3)	grip Right Average	grip strength Lt. (1)	grip strength Lt. (2)
UNITS:		years						inches		y=1 n=0	(0-100)	y=1 n=0	seconds	y=1 n=0	pounds	pounds	pounds	pounds	pounds	pounds
23-male	1	64	1	DM	0	2x/wk	AA	71	3	1	100	0	8.7	0	32	28	33	31.0	36	29
24-female	2	88	3	HTN, allergies	0	4x/wk	cauc	63	1	0	90	0	8.2	0	26	24	27	25.7	21	22
25-female	2	68	1	HTN,	0	daily	cauc	66	2	0	96	0	6.2	0	28	29	29	28.7	29	26
26-female	2	65	1	HTN arthritis, dizziness, falls	0	5x/wk	AA	72	3	1	87	0	9.1	0	35	37	37	36.3	32	32
27-female	2	67	1	HTN, thyroid,	0	2x/wk	AA	65	2	0	91	0	6.1	0	28	28	30	28.7	28	28
28-male	1	81	3	HTN, MI	0	3x/wk	cauc	68	2	0	100	0	6.2	0	52	51	50	51.0	50	48
29-female	2	80	3	HTN, depression	0	3x/wk	cauc	61	1	0	83	0	8.3	0	19	20	21	20.0	16	19
30-female	2	66	1	HTN, DM, CA, arthritis, dizziness, falls	1	3x/wk	AA	67	2	1	83	0	7.2	0	32	31	33	32.0	30	31
31-female	2	75	2	HTN, arthritis	0	daily	AA	66	2	0	96	0	8.6	0	26	25	27	26.0	31	26
32-female	2	76	2	HTN, heart murmur, DM, anemia	0	1x/wk	cauc	66	2	1	13	1	14.2	1	19	21	24	21.3	24	27
33-female	2	71	2	HTN	0	4x/wk	AA	65	2	0	100	0	5.9	0	37	29	33	33.0	19	30

Participant No.-Gender	grip strength Lt. (3)	grip Left average	grip fall risk	unilateral reach (1)	unilateral reach (2)	unilateral reach (3)	unilateral reach average	Unilateral fall risk <10"	unilateral reach to height ratio	bilateral reach (1)	bilateral reach (2)	bilateral reach (3)	bilateral reach average	bilateral reach to height ratio	combined fall risk score
UNITS:	pounds	pounds	y=1 n=0	inches	inches	inches	inches	y=1 n=0	%	inches	inches	inches	inches	%	
23-male	32	32.3	0	13.5	13.8	14.0	13.8	0	19.4	10.0	10.0	9.5	9.8	13.8	1
24-female	23	22.0	0	10.0	9.0	9.3	9.4	1	14.9	8.0	8.8	8.3	8.3	13.2	0
25-female	29	28.0	0	13.0	14.3	15.0	14.1	0	21.3	11.0	13.5	14.0	12.8	19.4	0
26-female	31	31.7	0	10.5	12.0	12.0	11.5	0	16.0	8.0	9.0	8.3	8.4	11.7	1
27-female	32	29.3	0	13.0	13.3	12.3	12.8	0	19.7	12.0	13.0	13.0	12.7	19.5	0
28-male	48	48.7	0	11.5	13.1	12.3	12.3	0	18.1	10.5	9.5	11.3	10.4	15.3	0
29-female	21	18.7	0	8.0	9.3	9.0	8.8	1	14.3	5.0	7.5	8.3	6.9	11.3	0
30-female	33	31.3	0	11.4	12.4	11.1	11.6	0	17.4	9.0	11.0	10.3	10.1	15.0	1
31-female	26	27.7	0	12.0	9.8	11.5	11.1	0	16.8	10.0	9.0	10.5	9.8	14.9	0
32-female	27	26.0	0	7.5	8.5	7.5	7.8	1	11.9	5.0	6.5	4.5	5.3	8.1	3
33-female	28	25.7	0	9.5	11.0	11.0	10.5	0	16.2	9.3	8.5	8.5	8.8	13.5	0

Participant No.-Gender	Gender Catergory (1) male (2) female	Age	Age Category (1) 60-69 (2) 70-79 (3) 80+	medical info	assist device? (1) yes (0) no	exercise	race	Height	Height Category (1) short (2) medium (3) tall	demographic fall risk	ABC score	ABC fall risk	Tug time	Tug fall risk	grip strength Rt. (1)	grip strength Rt. (2)	grip strength Rt. (3)	grip Right Average	grip strength Lt. (1)	grip strength Lt. (2)
UNITS:		years						inches		y=1 n=0	(0-100)	y=1 n=0	seconds	y=1 n=0	pounds	pounds	pounds	pounds	pounds	pounds
34-female	2	65	1	none	0	4x/wk	AA	62	1	0	95	0	7.2	0	29	28	28	28.3	28	28
35-female	2	66	1	HTN,	0	daily	cauc	61	1	0	80	0	8.5	0	17	18	18	17.7	20	18
36-femal	2	65	1	HTN, heart murmur, arthritis	0	5x/wk	AA	60	1	0	98	0	8.8	0	32	33	34	33.0	30	31
37-female	2	73	2	HN, CA	0	5x/wk	AA	66	2	1	100	0	7.5	0	38	37	34	36.3	32	29
38-female	2	66	1	HTN, heart murmur	0	2x/wk	cauc	66	2	0	93	0	9.1	0	38	38	35	37.0	36	35
39-female	2	69	1	htn, HEART MURMUR	0	WEEKLY	cauc	66	2	0	99	0	8.6	0	34	34	36	34.7	29	33
40-female	2	75	2	HTN, arthritis	0	2x/wk	cauc	62	1	0	99	0	7.1	0	27	26	28	27.0	26	25
41-female	2	65	1	HTN, arthritits	0	3x/wk	cauc	66	2	0	96	0	8.8	0	26	24	27	25.7	28	27
42- Female	2	86	3	HTN, pacemaker, stroke, osteoporosis	1	none	cauc	58	1	1	55	1	14.3	1	14	16	13	14.3	13	15
43-Female	2	79	2	htn	0	2x/wk	cauc	62	1	0	75	0	10.5	1	15	16	16	15.7	14	16
44-FEMALE	2	90	3	HTN, arthritis	1	NONE	cauc	60	1	1	65	1	14.5	1	13	14	15	14.0	13	12

Participant No.-Gender	grip strength Lt. (3)	grip Left average	grip fall risk	unilateral reach (1)	unilateral reach (2)	unilateral reach (3)	unilateral reach average	Unilateral fall risk <10"	unilateral reach to height ratio	bilateral reach (1)	bilateral reach (2)	bilateral reach (3)	bilateral reach average	bilateral reach to height ratio	combined fall risk score
UNITS:	pounds	pounds	y=1 n=0	inches	inches	inches	inches	y=1 n=0	%	inches	inches	inches	inches	%	
34-female	27	27.7	0	11.5	13.0	13.0	12.5	0	20.2	10.5	11.5	11.5	11.2	18.0	0
35-female	18	18.7	0	9.5	10.3	9.4	9.7	1	15.9	8.5	8.0	9.3	8.6	14.1	0
36-femal	31	30.7	0	13.0	13.9	14.4	13.8	0	22.9	11.5	12.5	12.9	12.3	20.5	0
37-female	36	32.3	0	16.8	16.3	15.3	16.1	0	24.4	12.5	12.6	13.8	13.0	19.6	1
38-female	32	34.3	0	13.8	12.3	13.0	13.0	0	19.7	10.0	11.8	12.8	11.5	17.4	0
39-female	33	31.7	0	10.0	11.5	10.5	10.7	0	16.2	10.0	8.4	10.0	9.5	14.3	0
40-female	25	25.3	0	14.9	16.5	15.5	15.6	0	25.2	11.5	13.2	12.8	12.5	20.1	0
41-female	27	27.3	0	11.8	9.8	10.3	10.6	0	16.0	10.8	8.3	10.5	9.8	14.9	0
42- Female	14	14.0	1	4.0	5.0	4.0	4.3	1	7.5	4.0	4.0	4.0	4.0	6.9	4
43-Female	15	15.0	1	9.0	10.0	11.0	10.0	1	16.1	9.0	9.0	10.0	9.3	15.1	2
44-FEMALE	14	13.0	1	8.0	9.0	7.0	8.0	1	13.3	7.0	6.0	8.0	7.0	11.7	4

Participant No.-Gender	Gender Catergory (1) male (2) female	Age	Age Category (1) 60-69 (2) 70-79 (3) 80+	medical info	assist device? (1) yes (0) no	exercise	race	Height	Height Category (1) short (2) medium (3) tall	demographic fall risk	ABC score	ABC fall risk	Tug time	Tug fall risk	grip strength Rt. (1)	grip strength Rt. (2)	grip strength Rt. (3)	grip Right Average	grip strength Lt. (1)	grip strength Lt. (2)
UNITS:		years						inches		y=1 n=0	(0-100)	y=1 n=0	seconds	y=1 n=0	pounds	pounds	pounds	pounds	pounds	pounds
45-female	2	75	2	FX BACK, FALL HX	0	3X/WK	cauc	66	2	1	70	0	10.5	1	18	19	16	17.7	18	17
46-MALE	1	66	1	NONE	0	DAILY	cauc	71	3	0	90	0	6.5	0	42	45	50	45.7	40	45
47-female	2	65	1	NONE	0	3X/WK	cauc	67	2	0	95	0	7.0	0	20	19	17	18.7	18	17
48 MALE	1	66	1	NONE	0	5X/WK	cauc	71	3	0	93	0	6.0	0	45	46	42	44.3	42	41
49 FEMALE	2	65	1	HTN	0	2X/WK	cauc	68	2	0	85	0	8.5	0	16	18	17	17.0	16	17
50 MALE	1	65	1	HTN, UE SURGERY	0	DAILY	cauc	64	1	0	100	0	6.5	0	29	30	35	31.3	29	27
51 FEMALE	2	66	1	htn	0	4x/wk	cauc	70	3	0	98	0	7.0	0	21	22	19	20.7	19	18
52 female	2	70	2	DM, ASTHMA, HTN, hx of falls	0	NONE	cauc	66	2	1	63	1	11.5	1	14	15	13	14.0	15	14
53 MALE	1	63	1	SHOULDER SURGERY	0	none	cauc	70	3	0	95	0	8.5	0	40	45	44	43.0	41	42
54-Female	2	77	2	DM, HTN	0	NONE	cauc	64	1	1	65	1	13.5	1	16	14	15	15.0	14	13
55 male	1	80	3	stroke, MI, HTN	1	none	cauc	70	3	1	60	1	14.0	1	20	21	18	19.7	15	16

Participant No.-Gender	grip strength Lt. (3)	grip Left average	grip fall risk	unilateral reach (1)	unilateral reach (2)	unilateral reach (3)	unilateral reach average	Unilateral fall risk <10"	unilateral reach to height ratio	bilateral reach (1)	bilateral reach (2)	bilateral reach (3)	bilateral reach average	bilateral reach to height ratio	combined fall risk score
UNITS:	pounds	pounds	y=1 n=0	inches	inches	inches	inches	y=1 n=0	%	inches	inches	inches	inches	%	
45-female	15	16.7	0	11.0	10.0	9.0	10.0	1	15.2	9.0	10.0	8.0	9.0	13.6	2
46-MALE	46	43.7	0	19.0	16.0	18.0	17.7	0	24.9	15.0	14.0	17.0	15.3	21.6	0
47-female	18	17.7	0	12.0	14.0	13.0	13.0	0	19.4	12.0	11.0	12.0	11.7	17.4	0
48 MALE	39	40.7	0	18.0	19.0	17.0	18.0	0	25.4	16.0	15.0	14.0	15.0	21.1	0
49 FEMALE	15	16.0	0	13.0	15.0	14.0	14.0	0	20.6	11.0	12.0	10.0	11.0	16.2	0
50 MALE	28	28.0	0	15.0	16.0	14.0	15.0	0	23.4	13.0	13.0	14.0	13.3	20.8	0
51 FEMALE	20	19.0	0	15.0	16.0	15.0	15.3	0	22.1	13.0	12.0	13.0	12.7	18.2	0
52 female	15	14.7	1	10.0	11.0	11.0	10.7	0	16.2	10.0	9.0	9.0	9.3	14.1	4
53 MALE	40	41.0	0	15.0	16.0	15.0	15.3	0	21.9	12.0	13.0	11.0	12.0	17.1	0
54-Female	14	13.7	1	8.0	7.5	8.5	8.0	1	12.5	7.0	8.0	7.5	7.5	11.7	4
55 male	19	16.7	1	6.0	6.5	6.0	6.2	1	8.8	5.0	5.5	5.5	5.3	7.6	4

Participant No.-Gender	Gender Catergory (1) male (2) female	Age	Age Category (1) 60-69 (2) 70-79 (3) 80+	medical info	assist device? (1) yes (0) no	exercise	race	Height	Height Category (1) short (2) medium (3) tall	demographic fall risk	ABC score	ABC fall risk	Tug time	Tug fall risk	grip strength Rt. (1)	grip strength Rt. (2)	grip strength Rt. (3)	grip Right Average	grip strength Lt. (1)	grip strength Lt. (2)
UNITS:		years						inches		y=1 n=0	(0-100)	y=1 n=0	seconds	y=1 n=0	pounds	pounds	pounds	pounds	pounds	pounds
56 female	2	65	1	htn	0	none	cauc	70	3	0	85	0	9.0	0	20	18	19	19.0	17	16
57 male	1	66	1	htn, stroke, brain tumor, falls	0	none	cauc	70	3	1	78	0	9.0	0	27	25	28	26.7	24	22
58 male	1	62	1	none	0	daily	cauc	74	3	0	100	0	6.5	0	54	45	52	50.3	46	48
59 female	2	62	1	Liver, HTN	0	5x/wk	cauc	66	2	0	95	0	8.5	0	24	23	25	24.0	22	23
60 male	1	62	1	TKA, THA, HTN	0	2x/wk	cauc	73	3	0	90	0	7.0	0	48	50	52	50.0	49	46
61 Female	2	74	2	HTN, TKA, DM	1	2x/wk	AA	63	1	1	63	1	13.5	1	16	16	17	16.3	15	16
62 male	1	63	1	htn, dm, dizziness	0	none	cauc	71	3	1	75	0	11.5	1	30	32	34	32.0	30	29
63 female	2	62	1	htn, dm, MI	0	none	cauc	70	3	1	65	1	12.5	1	15	16	16	15.7	15	14
64 male	1	63	1	htn	0	3x/wk	cauc	72	3	0	99	0	6.5	0	45	48	47	46.7	42	45
65 female	2	62	1	none	0	3x/wk	cauc	67	2	0	98	0	7.0	0	25	28	24	25.7	22	23
66 female	2	87	3	arthritis, HTN, TIA	1	none	cauc	64	1	1	55	1	15.5	1	14	12	10	12.0	10	10

Participant No.-Gender	grip strength Lt. (3)	grip Left average	grip fall risk	unilateral reach (1)	unilateral reach (2)	unilateral reach (3)	unilateral reach average	Unilateral fall risk <10"	unilateral reach to height ratio	bilateral reach (1)	bilateral reach (2)	bilateral reach (3)	bilateral reach average	bilateral reach to height ratio	combined fall risk score
UNITS:	pounds	pounds	y=1 n=0	inches	inches	inches	inches	y=1 n=0	%	inches	inches	inches	inches	%	
56 female	17	16.7	0	14.0	15.0	13.0	14.0	0	20.1	12.0	13.0	13.0	12.7	18.2	0
57 male	21	22.3	1	13.0	14.0	12.0	13.0	0	18.6	12.0	11.0	12.0	11.7	16.7	2
58 male	47	47.0	0	17.0	16.0	16.5	16.5	0	22.3	15.0	15.0	14.5	14.8	20.0	0
59 female	24	23.0	0	15.0	14.0	15.0	14.7	0	22.2	13.0	14.0	14.0	13.7	20.7	0
60 male	50	48.3	0	15.0	15.0	16.0	15.3	0	21.0	13.0	14.0	14.0	13.7	18.7	0
61 Female	15	15.3	0	8.0	7.5	8.5	8.0	1	12.7	7.0	7.0	6.5	6.8	10.8	3
62 male	28	29.0	0	15.0	16.0	16.0	15.7	0	22.1	14.0	15.0	14.0	14.3	20.2	2
63 female	13	14.0	1	10.0	11.0	12.0	11.0	0	15.7	8.0	9.0	8.0	8.3	11.9	4
64 male	43	43.3	0	14.0	16.0	17.0	15.7	0	21.8	15.0	14.0	14.0	14.3	19.9	0
65 female	22	22.3	0	14.0	13.0	15.0	14.0	0	20.9	12.0	13.0	13.0	12.7	18.9	0
66 female	9	9.7	1	4.0	5.0	4.5	4.5	1	7.0	3.0	4.0	4.0	3.7	5.7	4